United Nations ECE/ENERGY/GE.3/2015/3

Economic and Social Council

Distr.: General
20 February 2015

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Sixth session
Geneva, 28 April – 1 May 2015
Item 12 of the provisional agenda
Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 to renewable energy resources

Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 to renewable energy resources

Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to renewable energy resources

Draft document prepared by the Task Force on Application of UNFC-2009 to Renewable Energy Resources*

* Please note that this draft document has been prepared by the Task Force on Application of UNFC-2009 to Renewable Energy Resources following careful consideration of all the comments received during the fifth session of the Expert Group on Resource Classification and from stakeholders during the public comment period in 2014. It is submitted to the Expert Group on Resource Classification for endorsement. The Task Force comprises Raffaella Cristianetti, Frank Denelle (Chair), Norbert Dolle, Gioia Falcone, James Primrose, Bernard Seiller, Jean-Alain Taupy and Daniel Trotman.

GE.15-03252 (E)

1503252

Please recycle

Contents

			Page
I.	Introduction		3
II.	Renewable energy definitions		3
	A.	Renewable Energy Resources	3
	B.	Defining the Project	4
	C.	Project Life Time	4
	D.	Entitlement	5
	E.	Development Plan	5
III.	Definition of categories and supporting explanations		5
IV.	Generic specifications		8
	A.	Use of numerical codes	8
	B.	Bridging document	9
	C.	Effective date	9
	D.	Commodity or product type	9
	E.	Basis for estimate	10
	F.	Reference point	10
	G.	Classification of Projects based on level of maturity	10
	H.	Distinction between E1, E2 and E3	10
	I.	Confidence levels for G1, G2 and G3	11
	J.	Distinction between recoverable quantities and in situ (in-place) quantities	11
	K.	Aggregation of quantities	12
	L.	Economic assumptions	12
	M.	Evaluator qualifications	13
	N.	Units and conversion factors	13
	O.	Documentation	13
	P.	Expansion of G4 to account for uncertainty	13
	Q.	Optional labels for estimates	13
	R.	Classification of quantities associated with Exploration Projects	14
	S.	Classification of additional quantities in place	14
	T.	Extracted quantities that may be saleable in the future	14
Annex I.	Glossary of terms		16

I. Introduction

1. The purpose of this document is to enable the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) incorporating Specifications for its Application (as set out in ECE Energy Series No. 42 and ECE/ENERGY/94) to Renewable Energy Resources. The existing Generic Specifications are repeated in Part IV of this document for consistency and additional context for application to Renewable Energy Resources is provided where deemed necessary. The intended use of this document is in conjunction with UNFC-2009 and its Generic Specifications.

2. These specifications represent "rules of application" of UNFC-2009 for Renewable Energy. The United Nations Sustainable Energy for All (SE4ALL) definition of Renewable Energy is adopted in this document. The definition is provided below:

"Renewable energy is energy that is derived from natural processes (e.g. sunlight and wind) that are replenished at a higher rate than they are consumed. Solar, wind, geothermal, hydro[1], and biomass are common sources of renewable energy".

3. The central concept in UNFC-2009 is the Project. Resources are the (finite) quantities that are estimated to be extracted during the life time of the Project, and are classified according to the status of the Project. The identification and definition of the Project therefore remains the fundamental starting point for the application of UNFC-2009 to Renewable Energy Resources.

II. Renewable energy definitions

A. Renewable Energy Resources

4. **Renewable Energy Source** is the equivalent of the terms "deposit" or "accumulation" used for fossil fuels and solid mineral resources. Renewable Energy Source is the primary energy (e.g. sun, wind, biomass, earth heat, river flow, tides, waves) available for extraction of (and conversion into) Energy Products. The main difference with fossil fuels or solid minerals is that, during the life time of the project, the renewable energy source is being replenished[2].

5. An **Energy Product** is directly linked to (or a direct replacement of) a fungible energy commodity and is saleable in an established market. Examples of energy products are electricity, heat and ethanol. Other products extracted from the Renewable Energy Source in the same extraction process may not qualify as an Energy Product, such as sugar.

[1] In this definition the term "hydro" includes energy generated from waves, currents and tides.

[2] The SE4ALL definition uses "replenished at a higher rate than consumed", but it is noted that alternative definitions describe renewable energy as being replenished *at an equal or higher rate than consumed* or that the replenishment rate may vary seasonally or depending on the type of project.

6. **Renewable Energy Resources** are the cumulative quantities of extracted[3] Energy Products from the Renewable Energy Source, measured at the Reference Point.

B. Defining the Project

7. The resource classification process consists of identifying a Project, or Projects, associated with a Renewable Energy Source, estimating the regenerative potential of Renewable Energy available, estimating that portion of those available quantities that can be extracted as Energy Products by each Project, and classifying the Project(s) based on project (technical) status and feasibility and on economic and social viability.

8. The Project is the link between the Renewable Energy Source and sales quantities of Energy Products and provides the basis for economic evaluation and decision-making. There is a clear recognition of risk versus reward for the investor, linked to uncertainties and/or variability in the Renewable Energy Source, the efficiency of the extraction process, energy product prices and market conditions (including policy support mechanisms) and social acceptability. In the early stages of evaluation, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail.

9. The cumulative quantity of Energy Products taken to the Project's economic, contractual or other time limit defines the Renewable Energy Resource quantity.

C. Project Life Time

10. The forecasted Renewable Energy Resources for a Project are constrained by the economic limit Project lifetime. Entitlement defines the quantities that accrue to project participants.

11. The *economic limit* is defined as the extraction rate beyond which the remaining cumulative net operating cash flows from the Project are negative, a point in time that defines the Project's economic life. A significant difference with non-renewable energy Projects is that the economic limit will often not be an appropriate basis for the resource assessment because renewable energy is normally replenished at an equal or higher rate than consumed[4] and other Project limitations may become relevant before the economic limit is reached.

12. Generally, it will be necessary to limit the resources to a defined Project lifetime of a number of years. This Project lifetime can be determined from the design basis of the facilities or key components of those facilities, or based on industry practice or benchmarks for similar Projects. Routine maintenance requirements do not constrain the Project lifetime, but a need for significant capital re-investment, requiring a new Project investment decision and/or regulatory approval, would have to be captured, from a resource assessment perspective, as a separate Project of lower maturity.

13. The reporting entity's *entitlement* (see Section D) to the Renewable Energy Resources may also be limited in time and, if of lesser duration than the design life of the facilities, will be the constraining factor for the entity's resource reporting.

---

[3] The term "extraction" is used in these Specifications. This term is equivalent to "conversion" as often used for Renewable Energy and "production" or "recovery", which are commonly used for petroleum reserves/resources. Both terms "extraction" and "conversion" are used in the Geothermal sector.

[4] While the output from a Renewable Energy Project might decrease over time (e.g. due to reducing efficiency in the conversion process) it can nonetheless remain cash flow positive for a very long time (e.g. hydroelectric projects).

D. Entitlement

14. A reporting entity's "entitlement" to Renewable Energy Resources is governed by applicable contracts. Key elements that provide the basis for the ability of the entity to recognize and report resources are: (i) access to the Renewable Energy Source; (ii) exposure to risks in the extraction process; and (iii) the opportunity for reward through the subsequent sales of the Energy Product(s).

E. Development Plan

15. In order to assign extractible resources to any class, except for category F4, a development plan needs to be defined consisting of one or more Projects. The level of detail appropriate for such a plan may vary according to the maturity of the Project and may also be specified by regulation.

III. Definition of categories and supporting explanations

16. The following text (noted in italics) is from the publication UNFC-2009 incorporating Specifications for its Application (ECE Energy Series No. 42 and ECE/ENERGY/94): *"UNFC-2009 is a generic principle-based system in which quantities are classified on the basis of the three fundamental criteria of economic and social viability (E), field Project status and feasibility (F), and geological knowledge (G), using a numerical coding system. Combinations of these criteria create a three-dimensional system. Categories (e.g. E1, E2, E3) and, in some cases, sub-categories (e.g. E1.1) are defined for each of the three criteria as set out and defined in Annexes I and II of the Generic Specifications.*

17. *The first set of categories (the E axis) designates the degree of favourability of social and economic conditions in establishing the commercial viability of the Project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development Projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to a Project that is extracting and selling a commodity, and reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological[5] knowledge and potential recoverability of the quantities. The categories and sub-categories are the building blocks of the system, and are combined in the form of "classes". UNFC-2009 can be visualized in three dimensions or represented in a practical two-dimensional abbreviated version."*

18. Additional context is added to Annex I "Definition of Categories and Supporting Explanations" of Part I of UNFC-2009 incorporating Specifications for its Application (ECE Energy Series No. 42 and ECE/ENERGY/94) where deemed necessary for the application of UNFC-2009 to Renewable Energy Resources. The original text from UNFC-2009 incorporating Specifications for its Application is shown in italics in Table 1 and the additional context for the application of UNFC-2009 to Renewable Energy Resources is shown in normal font.

[5] In the renewable context, the G set of categories does not necessarily represent the level of confidence in the geological knowledge and potential recoverability (except for Geothermal) but in other factors that play a role in the level of confidence associated with the Renewable Energy Source and the potential recoverability of the quantities of energy Resources from the Source.

Table 1.
Definition of Categories and Supporting Explanations

Category	Definition	Supporting Explanation (UNFC-2009, Part I, Annex I)	Additional Renewable Energy context
E1	*Extraction and sale has been confirmed to be economically viable*	*Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals contracts have been confirmed or there are reasonable expectations that all such approvals contracts will be obtained within a reasonable timeframe. Economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.*	Extraction is the process of converting a primary energy source (e.g. wind, solar power, biomass) into a marketable energy product (e.g. electricity, liquid transport fuel).
E2	*Extraction and sale is expected to become economically viable in the foreseeable future.*	*Extraction and sale has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic extraction and sale in the foreseeable future.*	
E3	*Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability*	*On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale in the foreseeable future; or, economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the assessment phase). Also included are quantities that are forecast to be converted, but which will not be available for sale.*	
F1	*Feasibility of extraction by a defined development project or mining operation has been confirmed.*	*Extraction is currently taking place; or, implementation of the development project is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a development project or mining operation.*	The term "development Project" is the "renewable energy Project" as described in Part II Category F4, i.e. in situ (in place) quantities, can be used to classify the currently non-extractable quantities at the geographical location of the defined Project due to, for example, site/area constraints, technology limitations and/or other constraints.
F2	*Feasibility of extraction by a defined development project or mining operation is subject*	*Preliminary studies demonstrate the existence of a project in such form, quality and quantity that the feasibility of extraction by a defined (at least in broad terms) development Project or mining operation can be evaluated.*	

Category	Definition	Supporting Explanation (UNFC-2009, Part I, Annex I)	Additional Renewable Energy context
	to further evaluation.	*Further data acquisition and/or studies may be required to confirm the feasibility of extraction.*	
F3	*Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.*	*Very preliminary studies (e.g. during the assessment phase), which may be based on a defined (at least in conceptual terms) development project or mining operation, indicate the need for further data acquisition in order to confirm the existence of a project in such form, quality and quantity that the feasibility of production can be evaluated.*	
F4	*No development project or mining operation has been identified.*	*In situ (in-place) quantities that will not be produced by any currently development project or mining operation.*	
G1	*Quantities associated with a known deposit that can be estimated with a high level of confidence.*	*For in situ (in-place) quantities, and for recoverable estimates of fossil energy and mineral resources that are extracted as solids, quantities are typically categorized discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The estimates are categorized as G1, G2 and/or G3 as appropriate.* *For recoverable estimates of fossil energy and mineral resources that are extracted as fluids, their mobile nature generally precludes assigning recoverable quantities to discrete parts of an accumulation. Recoverable quantities should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorised on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.*	The G-axis represents the level of confidence in estimates of the quantities of extractable, or potentially extractable, Renewable Energy Resources associated with the Project. These could be considered as reflecting uncertainties impacting the Project and typically would cover areas such as meteorology, climatology, topography and other branches of geography, ecology, and geology (for Geothermal Projects). Typically the various uncertainties will combine to provide a full range of possible outcomes, comparable to the extraction of fluids in the petroleum sector. In such cases, categorization should reflect three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.
G2	*Quantities associated with a known deposit that can be estimated with a moderate level of confidence.*		
G3	*Quantities associated with a known deposit that can be estimated with a low level of confidence.*		
G4	*Estimated quantities associated with a potential deposit, based primarily on indirect evidence.*	*Quantities that are estimated during the initial assessment phase are subject to a substantial range of uncertainty as well as a major risk that no development project or mining operation may subsequently be implemented to extract the estimated quantities. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty in the size of the potential deposit should be documented (e.g. in the form of a*	Category G4 (Exploration Projects) is equally applicable to Renewable Energy quantities, based on the definition "Estimated quantities associated with a potential Project, based primarily on indirect evidence". G4 could be used to classify Renewable Energy from resource mapping studies (indirect evidence) that generally require more detailed and further (on-site)

Category	Definition	Supporting Explanation (UNFC-2009, Part I, Annex I)	Additional Renewable Energy context
		probability distribution). In addition, it is recommended that the chance (probability) that the potential deposit will become a deposit of any commercial significance is also documented.	data acquisitions and evaluation to confirm the (economic) potential of the Renewable Energy Source (the "Deposit") at location.

[a] The phrase "economically viable" encompasses economic (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal framework, environmental, social and all other non-technical factors that could directly impact the viability of a development project.

IV. Generic specifications

19. This section presents the Generic Specifications for the Application of UNFC-2009 (Part II of UNFC-2009 incorporating Specifications for its Application (ECE Energy Series No. 42 and ECE/ENERGY/94)) with additional guidance and clarification provided with respect to application in the context of Renewables where required. The original text from UNFC-2009 incorporating Specifications for its Application is noted in italics and additional guidance with respect to application in the context of Renewables is noted in normal font.

20. *In these generic specifications, the following words have specific meanings:*

- *"Shall" is used where a provision is mandatory;*
- *"Should" is used where a provision is preferred; and,*
- *"May" is used where alternatives are equally acceptable.*

21. *Where a generic specification is defined below, this sets a minimum standard for reporting under UNFC-2009. However, where a specification for the same issue exists in the Aligned System, and it fully meets the requirements of the generic specification defined below, that specification may be adopted.*

A. Use of numerical codes

21. *While the defined Classes and Sub-classes shown in Figures 2 and 3 of UNFC-2009 may be used as supplementary terminology, the relevant Numerical Code(s) shall always be reported in conjunction with the estimated quantity. For example, these may be documented in the form 111, 111+112, or 1.1;1.2;1, as appropriate.*

23. *Note that some Sub-categories are defined below that are in addition to those provided in Annex II of UNFC-2009. These optional Sub-categories have been identified as potentially useful in certain situations and have been defined herein in order to ensure consistency in their application. Nothing in this document shall preclude the possible use of additional Subclasses in the future that may be deemed to be useful in particular cases, especially where such Sub-classes facilitate the linkage to other systems and which may be defined in Bridging Documents.*

B. Bridging document

24. *Application of UNFC-2009 requires reference to a Bridging Document for the relevant commodity-specific specifications. The Bridging Document that was used as the basis for the evaluation shall be disclosed in conjunction with the reported quantities.*

Renewables – additional guidance:

The application of UNFC-2009 to Renewable Energy Resources will be supported by a set of commodity-specific specifications and/or bridging documents for Bioenergy (e.g. liquid, gaseous, power or heat from Biomass), Geothermal, Hydro, Solar and Wind energies.

C. Effective date

25. *Reported quantities are estimates of remaining quantities as at the Effective Date of the evaluation. The Effective Date shall be clearly stated in conjunction with the reported quantities. The evaluation should take into account all data and information available to the evaluator prior to the Effective Date. If information becomes available subsequent to the Effective Date, but prior to reporting, that could have significantly changed the estimated quantities as at the Effective Date, the likely effect of this information shall be disclosed.*

D. Commodity or product type

26. *Estimated quantities should be reported separately for each commodity or significant product type that will be sold, used, transferred or disposed of separately. Where estimates for different commodities or product types have been aggregated for reporting purposes, and separate estimates are not provided, the aggregated estimates shall be accompanied by a statement clarifying which commodities or product types have been aggregated and the conversion factor(s) used to render them equivalent for the purposes of aggregation*[6].

Renewables – additional guidance:

For Renewable Projects producing multiple sales products, the non-energy commodity output shall be excluded from the Renewable Energy Resource quantity. For example, the sugar produced from a Sugarcane Ethanol mill and the inorganic materials, such as silica, lithium, manganese, zinc and sulphur, that can be extracted from geothermal fluids represent a value to the project (and the revenue generated by their sale may be included in the economic evaluation of the project) but would not be classified as Renewable Energy Resources.

[6] *For example, crude oil volumes may be reported inclusive of condensate and natural gas liquids, in which case this fact shall be disclosed. Further, if gas volumes are converted to "oil equivalent" volumes and aggregated with crude oil estimates, this shall be disclosed. In addition, where resource estimates (e.g. oil, gas, coal and uranium) are converted into a measure of energy equivalency, the relevant conversion factors shall be disclosed.*

E. Basis for estimate

27. *Reported quantities may be those quantities attributable to the mine development Project as a whole, or may reflect the proportion of those quantities that is attributable to the reporting entity's economic interest in the mining operation or development Project*[7]. *The reporting basis shall be clearly stated in conjunction with the reported quantities. Government royalty obligations are often treated as a tax to be paid in cash and are therefore generally classified as a cost of operations. In such cases, the reported quantities may include the proportion attributable to the royalty obligation. Where the reported quantities exclude the proportion attributable to the royalty obligation, this shall be disclosed.*

F. Reference point

28. *The Reference Point is a defined location within an extraction and processing operation at which the reported quantities are measured or estimated. The Reference Point may be the commodity sales point from the extraction and processing operation or it may be an intermediate stage, such as pre-processing (if required), in which case the reported quantities would not take into account processing losses. The Reference Point shall be disclosed in conjunction with the reported quantities. Where the Reference Point is not the point of sale to third parties (or where custody is transferred to the entity's downstream operations), and such quantities are classified as E1, the information necessary to derive estimated sales quantities shall also be provided.*

Renewables – additional guidance:

In the case of renewables, the default for the Reference Point shall be the location in the extraction and conversion process at which the reported sales quantities of Renewable Energy Products are measured or estimated. Any deviation from this location shall be clearly justified. In all cases, the additional obligations for disclosure contained in the Generic Specification shall still apply.

G. Classification of Projects based on level of maturity

29. *Where it is considered appropriate or helpful to sub-classify Projects to reflect different levels of Project maturity, based on the current status of the Project, the optional Sub-classes shown in Figure 3 of UNFC-2009 may be adopted for reporting purposes. Additional guidance on the distinction between the Sub-classes of UNFC-2009 is provided in Annex V of ECE Energy Series No. 42 (ECE/ENERGY/94).*

H. Distinction between E1, E2 and E3

30. *The distinction between quantities that are classified on the Economic axis as E1, E2 or E3 is based on the phrase "reasonable prospects for economic extraction and sale in the foreseeable future". The definition of "foreseeable future" can vary depending on the*

[7] *The proportion of gross quantities attributable to a company will depend on the specific contractual arrangements governing development and extraction operations, and may be defined by regulation. For corporate reporting, the general principles used to determine net quantities shall be documented.*

commodity and hence more detailed specifications can be found in relevant commodity-specific systems that have been aligned with UNFC-2009.

31. *The Economic axis Categories encompass all non-technical issues that could directly impact the viability of a Project, including commodity prices, operating costs, legal fiscal framework, environmental regulations and known environmental or social impediments or barriers. Any one of these issues could prevent a new Project from proceeding (and hence quantities would be classified as E2 or E3, as appropriate), or it could lead to the suspension or termination of extractive activities in an existing operation. Where extractive activities are suspended, but there are "reasonable prospects for economic extraction and sale in the foreseeable future", remaining technically recoverable quantities shall be reclassified from E1 to E2. Where "reasonable prospects for economic extraction and sale in the foreseeable future" cannot be demonstrated, remaining quantities shall be reclassified from E1 to E3.*

I. Confidence levels for G1, G2 and G3

32. *The level of confidence for quantities that are classified on the Geological axis as G1, G2 and G3 is defined as "high", "medium" and "low", respectively. These are not specified more precisely at a generic level because there are fundamental differences between the approaches that are appropriate for commodities extracted as solids and those extracted as fluids, as discussed in the Supporting Explanation to the definitions of these Categories in UNFC-2009. More detailed specifications can therefore be found in relevant commodity specific systems that have been aligned with UNFC-2009.*

Renewables – additional guidance:

Typical uncertainties that impact the level of confidence in the estimated quantities of Renewable Energy Resources are related to meteorology, climatology, ecology, geography and geology (for Geothermal Projects).

J. Distinction between recoverable quantities and in situ (in-place) quantities

33. *Other than quantities that are classified on the Feasibility axis as F4, all reported quantities shall be limited to those quantities that are potentially recoverable on the basis of existing technology or technology currently under development, and are associated with actual or possible future exploration development Projects or mining operations. For solid minerals Projects where the ultimate extraction methodology has yet to be confirmed (E2F2), in situ quantities may be reported, provided that there are "reasonable prospects for economic extraction and sale" of all such quantities in the foreseeable future. If in situ quantities are reported and it is expected that the extraction methodology will lead to significant losses and/or grade dilution, this shall be disclosed, e.g. in a footnote. In the absence of any consideration of potential economic recoverability, all reported quantities shall be classified as F4. For commodities extracted as fluids, the recovery factor is usually a major uncertainty and hence this should always be taken into account for such Projects (F2 and F3) and shall be accommodated using the G-axis Categories*[8].

[8] *As discussed in Annex I of UNFC-2009 (G1/G2/G3 Supporting Explanation).*

Renewables – additional guidance:

Category F4, i.e. in situ (in place) quantities, can be used to classify currently non-extractable quantities at the geographical location of the defined Project (e.g. the area of the land lease) due to, for example, site/area constraints, technology limitations and/or other constraints. Examples are water over the spillways for hydroelectric projects or only partial availability of the leased land for a solar project due to heavy vegetation.

K. Aggregation of quantities

34. *Estimated quantities associated with mining operations or development Projects that are classified in different Categories on the Economic or Feasibility axis shall not be aggregated with each other without proper justification and disclosure of the methodology adopted*[9]. *In all cases, the specific Classes that have been aggregated shall be disclosed in conjunction with the reported quantity (e.g. 111+112+221+222) and a footnote added to highlight the fact that there is a risk that Projects that are not classified as E1F1 (Commercial Projects) may not eventually achieve commercial operation.*

35. *Where estimated quantities have been aggregated from multiple Projects, consideration should be given to sub-dividing the aggregated totals by deposit type and by location (e.g. offshore vs. onshore).*

L. Economic assumptions

36. *In accordance with the definitions of E1, E2 and E3, economic assumptions shall be based on current market conditions and realistic assumptions of future market conditions. Except where constrained by regulation, assumptions of future market conditions should reflect the view of either:*

(a) The organization responsible for the evaluation;

(b) The view of a competent person[10] *or independent evaluator; or,*

(c) An externally published independent view, which is considered to be a reasonable forecast of future market conditions. The basis for the assumptions (as opposed to the actual forecast) shall be disclosed.

Renewables – additional guidance:

Current market conditions and realistic assumptions of future market conditions should include policy support mechanisms for Renewable Energy, but shall not assume that such mechanisms will become more beneficial in the future unless already specified in the regulation.

[9] *Note that regulatory bodies may explicitly preclude such aggregation in corporate reporting under any circumstances.*

[10] *Note that "competent person" may be defined by regulation.*

M. Evaluator qualifications

37. *Evaluators must possess an appropriate level of expertise and relevant experience in the estimation of quantities associated with the type of deposit under evaluation. More detailed specifications can be found in relevant commodity-specific systems that have been aligned with UNFC-2009.*

N. Units and conversion factors

38. *In order to facilitate global comparability of resource estimates, it is recommended that the Système International d'Unités (SI units) is used for reporting of resource quantities. However, it is recognized that there are traditional measurement units that are widely used and accepted for certain commodities, where such units are used for reporting purposes, conversion factors to SI units shall be provided. Similarly, where quantities are converted from volume or mass to energy equivalents, or other conversions are applied, the conversion factors shall be disclosed.*

O. Documentation

39. *Estimates of resource quantities shall be documented in sufficient detail that would allow an independent evaluator or auditor to clearly understand the basis for estimation of the reported quantities and their classification.*[11]

P. Expansion of G4 to account for uncertainty

40. *In some situations, it may be helpful to express a range of uncertainty for quantities that are classified on the Geological axis as G4, e.g. Exploration Projects. In such cases, the following specification shall apply:*

(a) G4.1: low estimate of the quantities;

(b) G4.2: incremental amount to G4.1 such that G4.1+G4.2 equates to a best estimate of the quantities;

(c) G4.3: incremental amount to G4.1+G4.2 such that G4.1+G4.2+G4.3 equates to a high estimate of the quantities.

42. *Category G4, when used alone, shall reflect the best estimate and is equal to G4.1+G4.2.*

Q. Optional labels for estimates

41. *Where it is considered appropriate or helpful to use labels in addition to the numerical codes for a range of estimates for a specific development Project or mining operation, the terms "Low Estimate", "Best Estimate" and "High Estimate" may be used to correspond to quantities that are classified on the Geological axis as G1, G1+G2 and G1+G2+G3 respectively.*

---

[11] *Note that this is an obligation for ensuring that appropriate internal documentation is generated and kept, and is not an obligation for external disclosure of such information.*

R. Classification of quantities associated with Exploration Projects

42. *In some situations, it may be helpful to sub-classify Exploration Projects on the basis of their level of maturity. In such cases, the following specification shall apply:*

(a) F3.1: where site-specific geological studies and exploration activities have identified the potential for an individual deposit with sufficient confidence to warrant drilling or testing that is designed to confirm the existence of that deposit in such form, quality and quantity that the feasibility of extraction can be evaluated;

(b) F3.2: where local geological studies and exploration activities indicate the potential for one or more deposits in a specific part of a geological province, but requires more data acquisition and or evaluation in order to have sufficient confidence to warrant drilling or testing that is designed to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated;

(c) F3.3: at the earliest stage of exploration activities, where favourable conditions for the potential discovery of deposits in a geological province may be inferred from regional geological studies.

Renewables – additional guidance:

Instead of terms such as "site-specific geological studies", "exploration activities", "drilling" and "testing" use "site-specific studies" or "data acquisition activities" that are relevant to corresponding Renewable Energy commodities. The term "Geological province" remains applicable to Geothermal projects but can be replaced by "Geographic area" for other Renewable Energy commodities.

S. Classification of additional quantities in place

43. *In some situations, it may be helpful to sub-classify Additional Quantities in Place on the basis of the current state of technological developments. In such cases, the following specification shall apply:*

(a) F4.1: the technology necessary to recover some or all of the these quantities is currently under active development, following successful pilot studies on other deposits, but has yet to be demonstrated to be technically feasible for the style and nature of deposit in which that commodity or product type is located;

(b) F4.2: the technology necessary to recover some or all of the these quantities is currently being researched, but no successful pilot studies have yet been completed;

(c) F4.3: the technology necessary to recover some or all of these quantities is not currently under research or development.

T. Extracted quantities that may be saleable in the future

44. *The Sub-categories of E3 permit a distinction to be made between those quantities that may be forecast to be extracted, but which will not be available for sale (E3.1) and those for which there are currently no reasonable prospects for economic extraction and sale in the foreseeable future (E3.3). In the former case, the quantities are those that will be used, lost, destroyed or otherwise disposed of during the extraction process, and hence will not be made available for sale, such as natural gas that is produced in association with oil and is then flared into the atmosphere or used on-site for operational purposes.*

45. *In some situations, however, quantities may be extracted to the surface and then stored in some way for possible economic sale in the future and these may be assigned to E3.3 (and subsequently moved to E2 and E1 as appropriate[12]).*

[12] *One example is natural gas that has been produced to surface, but then injected back underground into the same or a different rock formation in such a way that it remains available for possible extraction and sale in the future. Another example would be thorium that has been extracted along with other, commercially saleable, commodities, but where there is no current market for the commodity. Provided that it is then stored in a manner in which it remains available for future commercial sale, it may be assigned to E3.3.*

Annex I

Glossary of terms[13]

Term	*Definition*
Aligned System	*A classification system that has been aligned with UNFC-2009 as demonstrated by the existence of a Bridging Document that has been endorsed by the Expert Group on Resource Classification.*
Bridging Document	*A document that explains the relationship between UNFC-2009 and another classification system, including instructions and guidelines on how to classify estimates generated by application of that system using the UNFC-2009 Numerical Codes*
Category	*Primary basis for classification using each of the three fundamental Criteria of economic and social viability (related Categories being E1, E2, and E3), field Project status and feasibility (related Categories being F1, F2, F3 and F4), and geological knowledge (related Categories being G1, G2, G3 and G4). Definitions of Categories are provided in Annex I to UNFC-2009.*
Class(es)	*Primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes).*
Complementary texts	*Additional texts to provide mandatory requirements (i.e. Specifications) and further guidance regarding the application of UNFC-2009. (This Specifications Document is an example of a complementary text.)*
CRIRSCO Template	*The CRIRSCO Template of 2013 is the system developed by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) for solid minerals and, for the purposes of this Specifications Document, includes the reporting codes and standards that are aligned with it.*
Criteria	*UNFC-2009 utilizes three fundamental Criteria for reserve and resource classification: economic and social viability; field Project status and feasibility; and, geological knowledge. These Criteria are each subdivided into Categories and Sub-categories, which are then combined in the form of Classes or Sub-classes.*
Energy Product	Output from a Renewable Energy Project that is directly linked to (or a direct replacement of) a fungible energy commodity and is saleable in an established market..
Evaluator	*Person, or persons, performing resource estimation and/or*

[13] Additional terms are added to the Glossary of Terms included in Annex I of Part II of "UNFC-2009 incorporating Specifications for its Application" (ECE Energy Series No. 42 and ECE/ENERGY/94) where deemed necessary for the application of UNFC-2009 to Renewable Energy Resources. The original text is shown in italics and the additional terms for the application of UNFC-2009 to Renewable Energy Resources are shown in normal font.

Term	*Definition*
	Classification
Exploration Project	*A Project that is associated with one or more Potential Deposits (as defined below).*
Generic Specifications	*Specifications (as documented in this Specifications Document) that apply to the classification of quantities of any commodity using UNFC-2009.*
Known Deposit	*A deposit that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant commodity-specific Aligned Systems.*
Mapping Document	*The output of a comparison between another resource classification system and UNFC-2009, or between that system and existing Aligned Systems, which highlights the similarities and differences between the systems. A Mapping Document can provide the basis for assessing the potential for the other system to become an Aligned System through the development of a Bridging Document.*
Numerical Code	*Numerical designation of each Class or Sub-class of resource quantity as defined by UNFC-2009. Numerical Codes are always quoted in the same sequence (i.e. E;F;G).*
Potential Deposit	*A deposit that has not yet been demonstrated to exist by direct evidence (e.g. drilling and or sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. surface or airborne geophysical measurements). More detailed specifications can be found in relevant commodity-specific Aligned Systems.*
Project	*A Project is a defined development or mining operation which provides the basis for economic evaluation and decision-making. In the early stages of evaluation, including exploration, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail. Where no development or mining operation can currently be defined for all or part of a deposit, based on existing technology or technology currently under development, all quantities associated with that deposit (or part thereof) are classified in Category F4.*
PRMS	*Petroleum Resources Management System of 2007 (PRMS), which was approved by the Society of Petroleum Engineers (SPE) Board in March 2007 and endorsed by the World Petroleum Council (WPC), the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Evaluation Engineers (SPEE) and the Society of Exploration Geophysicists (SEG).*
Renewable Energy Resources	Renewable Energy Resources are the cumulative quantities of extracted and marketable Energy Products from the Renewable Energy Source, measured at the Reference Point.
Renewable Energy Source	Renewable Energy Source is the primary energy (e.g. sun, wind, biomass, earth heat, river flow, tides, waves) available for extraction of (and conversion into) Energy Products. The equivalent of the terms "deposit" or "accumulation" used for fossil fuels and solid mineral resources.

Specifications	*Additional details (mandatory rules) as to how a resource classification system is to be applied, supplementing the framework definitions of that system. Generic Specifications provided for the UNFC-2009 in this Specifications Document ensure clarity and comparability and are complementary to the commodity-specific requirements included in Aligned Systems, as set out in the relevant Bridging Document.*
Specifications Document	*Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009).*
Sub-categories	*Optional subdivision of Categories for each of the fundamental Criteria of economic and social viability, field Project status and feasibility, and geological knowledge. Definitions of Subcategories are provided in Annex II to UNFC-2009.*
Sub-classes	*Optional subdivision of resource classification based on Project maturity principles resulting from the combination of Subcategories. Project maturity sub-classes are discussed further in Annex V of the Specifications Document.*
Système International d'Unités	*Internationally recognized system of measurement and the modern form of the metric system. Prefixes and units are created and unit definitions are modified through international agreement as the technology of measurement progresses, and as the precision of measurements improves. Abbreviated to SI.*
UNFC-2009	*United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (ECE Energy series No. 39).*

United Nations ECE/ENERGY/GE.3/2015/4

Economic and Social Council

Distr.: General
23 February 2015

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Sixth session
Geneva, 28 April – 1 May 2015
Item 13 of the provisional agenda
Use of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for classifying injection projects

Use of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for classifying injection projects

Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to injection projects for the purpose of geological storage

Draft document prepared by the Task Force on Application of UNFC-2009 to Injection Projects*

* This document was prepared by the Task Force on Application of UNFC-2009 to Injection Projects and is submitted as a draft text for discussion by the Expert Group on Resource Classification at its sixth session. The Task Force comprises Karin Ask (Chair), Michelle Bentham, Simplicio Caluyong, Scott Frailey, Eva Halland, Wolf Heidug and Martin Hubbig.

GE.15-03487 (E)

1503487

Please recycle

Contents

		Page
I.	Introduction	3
II.	UNFC-2009 as applied to injection projects	3
	A. Categories and Sub-categories	3
	B. Classes and sub-classes	4
III.	Injection project definitions	6
	A. Geological Storage	6
	B. Defining the Project	6
	C. Storage Potential	7
	D. Quantities Stored	7
	E. Development Plan	7
	F. Project Life Time	8
	G. Economic Viability	8
	H. Storage Permission	8
IV.	Definition of categories and sub-categories with supporting explanations	8
V.	Generic specifications	12
	A. Use of numerical codes	13
	B. Bridging document	13
	C. Effective date	13
	D. Commodity or product type	14
	E. Basis for estimate	14
	F. Reference point	14
	G. Classification of projects based on level of maturity	14
	H. Distinction between E1, E2 and E3	14
	I. Confidence levels for G1, G2 and G3	15
	J. Distinction between stored quantities and in SITU storage potential	15
	K. Aggregation of quantities	15
	L. Economic assumptions	15
	M. Evaluator qualifications	16
	N. Units and conversion factors	16
	O. Documentation	16
	P. Expansion of G4 to account for uncertainty	16
	Q. Optional labels for estimates	16
	R. Classification of quantifies associated with screening projects	16
	S. Classification of additional quantities available for geological storage	17
	T. Quantities delivered for injection and storage that may not be stored	17
Annex I	Glossary of Terms	18

I. Introduction

1. The purpose of this document is to enable the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) incorporating Specifications for its Application (as set out in ECE Energy Series No. 42 and ECE/ENERGY/94), to Injection Projects for the purpose of Geological Storage.

2. The main focus in this document is on classifying Injection Projects related to the Geological Storage of carbon dioxide (CO_2). The same principles of project maturity should however also be applicable to other injection projects where a fluid is injected into a subsurface geological formation for storage.

3. The UNFC-2009 classifies quantities associated with projects. It was originally developed to classify fossil energy and mineral reserves and resources located on or below the Earth's surface. Resource classification is used in the oil and gas industry as well as the mining industry to assess the commercial attractiveness of different extraction projects. Each project is associated with a certain quantity that can be extracted, given a defined technical solution and a certain investment. Projects can be of different size and have different degree of maturity.

4. For Injection Projects for the purpose of Geological Storage, the resource is the Storage Potential[1] in a given reservoir available for geological storage. The quantity that is classified is the quantity of a given fluid, such as CO_2, that can be stored in this reservoir by implementing an Injection Project.

5. Text that has been kept unaltered from UNFC-2009 incorporating Specifications for its Application (ECE Energy Series No. 42 and ECE/ENERGY/94) is indicated in this document in italics for clarity.

6. The intended use of this document is in conjunction with the publication UNFC-2009 and its Generic Specifications (ECE Energy Series No. 42 and ECE/ENERGY/94).

II. UNFC-2009 as applied to injection projects

A. Categories and Sub-categories

7. In the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC-2009) text, the categories and sub-categories of the classification system are described as follows:

8. *"UNFC-2009 is a generic principle-based system in which quantities are classified on the basis of the three fundamental criteria of economic and social viability (E), field project status and feasibility (F), and geological knowledge (G), using a numerical coding system. Combinations of these criteria create a three-dimensional system. Categories*

[1] There is currently a lack of consensus in the Task Force on UNFC-2009 and Injection Projects for applying the term Storage Potential to all injection projects, including the most mature projects. The Task Force is continuing its work on finding an alternative term that better describes all levels of project maturity.

(e.g. E1, E2, E3) and, in some cases, sub-categories (e.g. E1.1) are defined for each of the three criteria as set out and defined in Annexes I and II.

9. *The first set of categories (the E axis) designates the degree of favourability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to a project that is extracting and selling a commodity, and reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities.*

10. *The categories and sub-categories are the building blocks of the system, and are combined in the form of "classes". UNFC-2009 can be visualized in three dimensions or represented in a practical two-dimensional abbreviated version.*[2]"

11. Definitions and supporting explanations for the different categories and sub-categories can be found in Part IV of this document. Minor changes have been made to the Explanations to facilitate the application to Injection Projects for the purpose of Geological Storage or to other forms of Underground Gas Storage, while keeping it as close to the original UNFC-2009 explanatory text as possible.

B. Classes and sub-classes

12. Figure 1 shows UNFC-2009, in its abbreviated version with primary classes and categories, adapted for application to Injection Projects for the purpose of Geological Storage. The classes and categories are the same as for extractive activities.

Figure 1.

Abbreviated version of UNFC-2009 with primary classes and categories adapted for application to injection projects for the purpose of geological storage

UNFC-2009 Classes Defined by Categories as Applied to Injection Projects for the Purpose of Geological Storage					
Total Storage Potential	Injected and Stored Quantities				
		Class	*Categories*		
			E	F	G
	Future storage by commercial injection projects	Commercial Injection Projects	1	1	1, 2, 3
	Future storage in known reservoirs by injection projects	Potentially Commercial Injection Projects	2	2	1, 2, 3
		Non-Commercial Injection Projects	3	2	1, 2, 3
	Storage Not Feasible		3	4	1, 2, 3
	Potential future storage in undiscovered reservoirs by	Screening Projects	3	3	4

[2] See Figures 1 and 2 in Part I of UNFC-2009 (ECE Energy Series No. 42 and ECE/ENERGY/94).

	injection projects				
	Storage Not Feasible		3	4	4

13. The Total Storage Potential is classified at a given date in terms of the following:

(a) Injected and Stored Quantities: Quantities of a fluid that have been injected and are currently stored in the reservoir;

(b) Commercial and Potentially Commercial Projects: Storage potential associated with a known reservoir where injection for the purpose of geological storage is ongoing or which may be used for storage in the future. The classification is based on technical and commercial studies related to defined injection activities;

(c) Non-Commercial Injection Projects: Additional storage potential associated with a known reservoir that will not be used for storage by any currently defined injection project;

(d) Screening Projects: Storage potential associated with an undiscovered reservoir that may be used for storage in the future provided that the reservoir is confirmed;

(e) Storage not feasible: Reservoir which will not be available for storage or where storage is for some reason not feasible.

14. As for extractive activities, additional generic sub-classes are also defined based on the Injection Projects sub-categories defined in Part IV of this document.

Figure 2.

UNFC-2009 classes and sub-classes defined by sub-categories, adapted for application to injection projects for the purpose of geological storage

UNFC Classes Defined by Categories and Sub-Categories as Applied to Injection Projects						
Total Storage Potential	Injected and Stored Quantities					
	Class		*Sub-class*	*Categories*		
				E	F	G
	Known Reservoir	Commercial Injection Projects	Active Injection	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Commercial Injection Projects	Development Pending	2	2.1	1, 2, 3
			Development on Hold	2	2.2	1, 2, 3
		Non-Commercial Injection Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development not Viable	3.3	2.3	1, 2, 3
		Storage Not Feasible		3.3	4	1, 2, 3
	Undiscovered Reservoir	Screening Projects	Storage Potential Identified	3.2	3.1	4
			Storage Potential Indicated	3.2	3.2	4

			Storage Potential Inferred	3.2	3.3	4
		Storage Not Feasible		3.3	4	4

15. Classifications other than the ones shown in Figure 2 can be generated by choosing appropriate combinations of categories, or by grouping or further subdividing the categories.

III. Injection project definitions

A. Geological Storage

16. The term Geological Storage refers mainly to permanent containment of carbon dioxide (CO_2) in deep subsurface geological formations, here referred to as reservoirs, with the purpose of isolating CO_2 emissions from the atmosphere. The application of UNFC-2009 described in this document has been developed primarily with the Geological Storage of CO_2 in mind, but can also be applied to other forms of injection projects where fluids are stored in geological formations.

17. Underground storage of Hydrogen is sometimes referred to as Geological Hydrogen Storage. As hydrogen storage is likely to be temporary rather than permanent, this is more comparable to Underground Gas Storage as described below.

18. Natural gas is often held in inventory underground. The most commonly used underground facilities are depleted reservoirs in oil and gas fields, aquifers and salt caverns. The main difference between such storage and Geological Storage of CO_2, apart from the fluid itself, is that the natural gas is only temporarily stored and will at some point be withdrawn from the reservoir. The storage reservoir can be used repeatedly for temporary storage and subsequent withdrawal. Several different quantity measures will be associated with such storage. The total quantity that can be stored will be the sum of the quantity that is currently in storage and can be withdrawn (often referred to as working gas), the quantity of permanent inventory gas necessary to maintain sufficient pressure for withdrawal purposes (base gas or "cushion" gas), and the quantity currently available for storage.

19. When an Underground Gas Storage is developed, the technical and economical maturity of the project activities associated with it can be classified according to the principles of UNFC-2009 as outlined in this document. The different quantities associated with the classified projects should always be clearly stated.

20. CO_2, nitrogen or natural gas is sometimes injected into a producing oil field in order to increase the amount of hydrocarbons that can be extracted. The resulting hydrocarbon resources can be classified using the UNFC-2009 as it is defined for extractive activities.

21. When geological storage of the injected CO_2 is part of the objective, the stored quantities can be classified in the same way applying UNFC-2009 as described in this document. The geological storage part of the project is likely to be developed in parallel with the hydrocarbon recovery part, and the two activities will in this case have the same level of maturity, but with two different quantities associated with it; the quantities of hydrocarbons that will be extracted and the quantity of CO_2 that will be stored.

B. Defining the Project

22. UNFC-2009 classifies quantities associated with projects. The injection project typically includes injection wells, monitoring wells, surface equipment, injection flow lines,

and an operations control centre. The project may include pressure relief wells and produced fluid processing equipment. Depending on the location of the custody transfer, a delivery pipeline may be included in the storage project.

23. One or more injection wells may be required to store a projected rate and quantity of fluid. The monitoring well(s) may be within the storage unit and/or above the overlying caprock or seal. The surface equipment may include injection lines and manifolds (and associated valves), a meter, and a pump or compressor (if needed to increase pipeline delivery pressure to injection wellhead pressure). An operations control centre may be at the injection site and/or remotely and is used to monitor and control injection operations.

24. The project should include estimates of storage quantities and injection rates. The reservoir, or the geologic formation planned to be used for storage and the respective overlying caprock, should be characterized to meet the project goals. Projections of investments and other costs as well as revenue from storage should be estimated.

25. Once a project has been defined, UNFC-2009 can be used to classify the quantities stored according to the technical and economical maturity of the defined project activities.

C. Storage Potential

26. The Storage Potential of a reservoir is the total amount of a given fluid that could be injected and stored in this reservoir, including amounts that could be dissolved in aquifer water, be trapped by chemical reaction or adsorbed onto the carbon in coal bed methane recovery. How much of the Total Storage Potential initially in place that will eventually be utilized for geological storage, will depend on the specifics of the individual projects that are classified.

D. Quantities Stored

27. In this document, the term Quantity refers to the quantity of a given fluid that could be stored in the reservoir being evaluated, given a defined project activity and a certain investment. The quantitative evaluation shall take into account both the geological knowledge of the subsurface at the time of the evaluation, and the engineering considerations relating to the reservoir properties as well as the chosen technical solution. The quantity stored in one reservoir may be the aggregated quantities from several sources, from one single source or part of the total quantity from one source, and vice versa.

E. Development Plan

28. In order for a project to be approved for development, a Plan for Development of the injection site and its operation must be prepared. The Development Plan typically includes timeline, design elements, and economics for the injection project. It should include required components of injection outside of the injection project definition, such as delivery pipeline and their effect on the injection project. The timeline should include lead time for equipment, drilling and completing wells, and for characterizing the reservoir as well as acquiring necessary injection permits and managements approval. The design elements should include well locations, completion techniques, drilling methods, site facilities (as needed), transportation, and the source of injection fluid. Economic evaluations should include source of revenue, as well as capital and operating expenses for the full Project Life Time. The duration of the availability of the injection fluids should be known. A risk assessment should always be part of the development plan.

F. Project Life Time

29. Feasibility of an injection project for the purpose of Geological Storage comprises two components:

(a) The injection of fluid; and

(b) The retention of the injected fluid through one or more trapping mechanisms.

30. An injection project will need to include activities also after the active injection has ceased, such as monitoring of any fluid movements and making sure that there is reasonable confidence that the injected fluid is retained in the reservoir. How this will affect the total life time of the project will depend on the specifics of the project, the reservoir, the injected fluid and the prevailing rules and regulations.

31. When an Injection Project is classified as technically and economically feasible according to UNFC-2009, the evaluation shall comprise the complete Project Life Time.

G. Economic Viability

32. In UNFC-2009, the phrase "Economically viable" encompasses economic factors (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal frameworks, environmental, social and all other non-technical factors that could directly impact the viability of a development project. This definition is highly relevant also for geologic storage projects, where the strictly economic feasibility of a project may depend on government subsidies or other incentives. Classifying a geological storage project as Economically Viable within UNFC-2009 requires that all relevant non-technical factors have been considered.

H. Storage Permission

33. Geological storage of CO_2, or storage of other fluids in subsurface geological formations, may be subject to different local, national and/or international regulations and requirements. Within the European Union (EU), CO_2 storage sites should not be operated without a Storage Permit. Such permits may be given independently by the EU Member States, and should be issued by an established or designated competent authority. All Storage Permits should also be made available to the European Commission. Other regulations may be relevant in other parts of the world.

34. In order for an injection project to be classified as Economically Viable according to UNFC-2009, all required Storage Permits or other relevant permits must be in place.

IV. Definition of categories and sub-categories with supporting explanations

35. Tables 1 and 2 show the definitions from UNFC-2009, together with a revised version of the same definitions as well as supporting explanations adapted for the application of UNFC-2009 to injection projects for the purpose of geological storage:

(a) "Extraction and sale" has been replaced with "Injection for the purpose of geological storage";

(b) "Screening phase" includes all projects where the Storage Potential has not yet been confirmed (undiscovered reservoirs).

Table 1.

Definition of categories and supporting explanations adapted for application of UNFC-2009 to injection projects for the purpose of geological storage

	UNFC-2009	UNFC-2009 applied to Injection Projects for the purpose of Geological Storage	
Category	*Definition*	*Definition*	*Supporting Explanation*
E1	*Extraction and sale has been confirmed to be economically viable.*	Injection for the purpose of geological storage has been confirmed to be economically viable [a].	Injection is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals/contracts have been confirmed or there are reasonable expectations that all such approvals/contracts will be obtained within a reasonable time frame. Economic viability is not affected by short-term adverse market conditions provided that longer term forecasts remain positive.
E2	*Extraction and sale is expected to become economically viable in the foreseeable future.*	Injection for the purpose of geological storage is expected to become economically viable in the foreseeable future.	Injection has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic injection and storage in the foreseeable future.
E3	*Extraction and sale is not expected to become economically viable in the foreseeable future, or the evaluation is at too early a stage to determine economic viability.*	Injection for the purpose of geological storage is not expected to become economically viable[a] in the foreseeable future, or the evaluation is at a too early a stage to determine economic viability[a].	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic injection in the foreseeable future; or, economic viability of injection cannot yet be determined due to insufficient information (e.g. during the screening phase).
F1	*Feasibility of extraction by a defined development project or mining operation has been confirmed.*	Feasibility of an injection project[b] for the purpose of geological storage has been confirmed.	Injection is currently taking place; or, implementation of an injection project is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of geological storage by implementing a defined injection project.
F2	*Feasibility of extraction by a defined development project or mining operation is subject to further evaluation.*	Feasibility of an injection project[b] for the purpose of geological storage is subject to further evaluation.	Preliminary studies demonstrate the existence of a Reservoir in such form, quality and quantity that the feasibility of geological storage by a defined injection project can be evaluated. Further data acquisition and/or studies may be required to confirm the feasibility of injection for the

	UNFC-2009	UNFC-2009 applied to Injection Projects for the purpose of Geological Storage	
Category	*Definition*	*Definition*	*Supporting Explanation*
			purpose of geological storage.
F3	*Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.*	Feasibility of an injection project[b] for the purpose of geological storage cannot be evaluated due to limited technical data.	Very preliminary studies (screening phase), which may be based on a defined injection project, indicate the need for further data acquisition and/or further geological studies in order to confirm the existence of a reservoir in such form, quality and quantity that the feasibility of injection for the purpose of geological storage can be evaluated.
F4	*No development project or mining operation has been identified.*	No injection project[b] for the purpose of geological storage has been identified.	Reservoir which may be suitable for injection for the purpose of geological storage but which will not be utilised by any currently defined injection project.
G1	*Quantities associated with a known deposit that can be estimated with a high level of confidence.*	Quantities associated with a known reservoir that can be estimated with a high level of confidence.	The G-axis represents the level of confidence in the estimated quantities of a fluid that can be stored in the reservoir through a defined injection project. The quantities are typically categorised discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the reservoir. The estimates are categorised as G1, G2 and/or G3 as appropriate. The quantities that can be stored should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorised on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.
G2	*Quantities associated with a known deposit that can be estimated with a moderate level of confidence.*	Quantities associated with a known reservoir that can be estimated with a moderate level of confidence.	
G3	*Quantities associated with a known deposit that can be estimated with a low level of confidence.*	Quantities associated with a known reservoir that can be estimated with a low level of confidence.	
G4	*Estimated quantities associated with a potential deposit, based on primary or indirect evidence.*	Estimated quantities associated with a potential reservoir, based on primary or indirect evidence.	Undiscovered storage quantities that are estimated during the screening phase. Normally subject to a substantial range of uncertainty as well as a major risk that no injection project may be implemented.

[a] The phrase "economically viable" encompasses economic (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal framework, environmental, social and all other non-technical factors that could directly impact the viability of a development project.

[b] A defined injection project comprises both the active injection phase and the retention phase, i.e. the full Project Life Time until there is reasonable confidence that the injected fluid is retained in the reservoir.

36. UNFC-2009 Sub-categories and their definitions have been revised as shown in Table 2 below for application to Injection projects for the purpose of Geological Storage.

Table 2.

UNFC-2009 Sub-categories with definitions adapted for application to injection projects for the purpose of geological storage

Category	*Sub-category*	*Sub-category Definition*
E1	E1.1	Injection for the purpose of geological storage is economic on the basis of current market conditions and realistic assumptions of future market conditions.
	E1.2	Injection for the purpose of geological storage is not economic on the basis of current market conditions and realistic assumptions of future market conditions, but is made viable through government subsidies and/or other considerations.
E2		**No Sub-categories defined**
E3	E3.1	Injection losses. Quantities that may be delivered to the injection site but which are lost in the transportation of surface facilities prior to injection. Equivalent to non-sales production.
	E3.2	Economic viability of injection for the purpose of geological storage cannot yet be determined due to insufficient information (e.g. during the exploration/screening phase).
	E3.3	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic injection for the purpose of geological storage in the foreseeable future.
F1	F1.1	Injection for the purpose of geological storage is currently taking place.
	F1.2	Capital funds have been committed and implementation of an injection project for the purpose of geological storage is underway.
	F1.3	Sufficiently detailed studies have been completed to demonstrate the feasibility of an injection project for the purpose of geological storage.
F2	F2.1	Project activities are on-going to justify injection for the purpose of geological storage in the foreseeable future.
	F2.2	Project activities are on hold and/or where justification as a commercial injection project for the purpose of geological storage may be subject to significant delay.
	F2.3	There are no current plans to develop or to acquire additional data at the time due to limited potential.

V. Generic specifications[3]

37. *In these generic specifications, the following words have specific meanings:*

- *"Shall is used where a provision is mandatory*
- *"Should" is used where a provisions is preferred; and*

[3] In this Section, where a specification is equally valid for injection projects and extraction projects, the original text from the Generic Specification for the Application of UNFC-2009 (see "UNFC-2009 incorporating Specifications for its Application" ECE Energy Series No. 42 (ECE/ENERGY/94), Part II, section VI) has been kept unaltered and is shown in italics. All modified wording is shown as underlined text.

- *"May" is used where alternatives are equally acceptable.*

38. Where a specification is equally valid for injection projects and extraction projects, the original text from the Generic Specification for the Application of UNFC-2009 (see "UNFC-2009 incorporating Specifications for its Application" ECE Energy Series No. 42 (ECE/ENERGY/94), Part II, section VI) has been kept unaltered and is shown in italics. In other cases, the text has been modified to better suit the purpose of classifying injection projects for the purpose of geological storage.

39. *Where a generic specification is defined below, this sets a minimum standard for reporting under UNFC-2009. However, if a specification for the same issue exists in an Aligned System, and it fully meets the requirements of the generic specification defined below, that specification may be adopted.* (Currently, no other system for classifying Injection Projects has been aligned with UNFC-2009).

A. Use of numerical codes

40. *While the defined Classes and Sub-classes shown in Figures 2 and 3 of UNFC-2009 may be used as supplementary terminology, the relevant Numerical Code(s) shall always be reported in conjunction with the estimated quantity. For example, these may be documented in the form 111, 111+112, or 1.1; 1.2; 1, as appropriate.*

41. *Note that some Sub-categories are defined below that are in addition to those provided in Annex II of UNFC-2009. These optional Sub-categories have been identified as potentially useful in certain situations and have been defined herein in order to ensure consistency in their application. Nothing in this document shall preclude the possible use of additional Sub-classes in the future that may be deemed to be useful in particular cases, especially where such Sub-classes facilitate the linkage to other systems and which may be defined in Bridging Documents.*

B. Bridging document

42. *Application of UNFC-2009 to extraction projects requires reference to a Bridging Document for the relevant commodity-specific specifications. The Bridging Document that was used as the basis for the evaluation shall be disclosed in conjunction with the reported quantities.* There is currently no other universally accepted classification system for injection projects for the purpose of geological storage, for which a Bridging Document can be prepared. UNFC-2009 can still be applied to injection projects as described in this document.

C. Effective date

43. *Reported quantities are estimates of remaining quantities as at the Effective Date of the evaluation. The Effective Date shall be clearly stated in conjunction with the reported quantities. The evaluation should take into account all data and information available to the evaluator prior to the Effective Date. If information becomes available subsequent to the Effective Date, but prior to reporting, that could have significantly changed the estimated quantities as at the Effective Date, the likely effect of this information shall be disclosed.*

D. Commodity or product type

44. For extraction projects, *estimated quantities should be reported separately for each commodity or significant product type that will be sold, used, transferred or disposed of separately.* When UNFC-2009 is applied to injection projects, only one fluid is normally expected to be stored in the same reservoir. When this fluid comes from more than one source, it may be relevant to report quantities separately for separate sources.

45. If UNFC-2009 is applied to Underground Gas Storage projects, it may be relevant to report different quantities such as total storage, working gas and base gas separately.

E. Basis for estimate

46. *Reported quantities may be those quantities attributable to* the injection project as a whole, *or may reflect the proportion of those quantities that is attributable to the reporting entity's economic interest in* the injection project. *The reporting basis shall be clearly stated in conjunction with the reported quantities.*

F. Reference point

47. *The Reference Point is a defined location within an* injection operation *at which the reported quantities are measured or estimated. The Reference Point may be the* custody transfer point from a pipeline operator to a storage site operator, or the last metered quantity prior to injection. *The Reference Point shall be disclosed in conjunction with the reported quantities. Where the Reference Point is not the point* where custody is transferred to the storage site (or the entity's downstream operations), *and such quantities are classified as E1, the information necessary to derive estimated quantities shall also be provided.*

G. Classification of projects based on level of maturity

48. *Where it is considered appropriate or helpful to sub-classify projects to reflect different levels of project maturity, based on the current status of the project, the optional Sub-classes shown in Figure 3 of UNFC-2009 (Part I) may be adopted for reporting purposes. Additional guidance on the distinction between the Sub-classes of UNFC-2009 is provided in Annex V* of the same document. Sub-category definitions for application to injection projects for the purpose of geologic storage are provided in Part III of this document.

H. Distinction between E1, E2 and E3

49. *The distinction between quantities that are classified on the Economic axis as E1, E2 or E3 is based on the phrase "reasonable prospects for economic* injection for the purpose of geological storage *in the foreseeable future". The definition of "foreseeable future" can vary depending on* the stored fluid.

50. *The Economic axis Categories encompass all non-technical issues that could directly impact the viability of a project, including commodity prices, operating costs, legal/fiscal framework, environmental regulations and known environmental or social impediments or barriers. Any one of these issues could prevent a new project from proceeding (and hence quantities would be classified as E2 or E3, as appropriate), or it could lead to the suspension or termination of* injection *activities in an existing operation. Where* injection *activities are suspended, but there are "reasonable prospects for economic*

injection and storage *in the foreseeable future", remaining technically* available storage *quantities shall be reclassified from E1 to E2. Where "reasonable prospects for economic* injection and storage *in the foreseeable future" cannot be demonstrated, remaining* storage *shall be reclassified from E1 to E3.*

I. Confidence levels for G1, G2 and G3

51. *The level of confidence for quantities that are classified on the Geological axis as G1, G2 and G3 is defined as "high", "medium" and "low", respectively. These are not specified more precisely at a generic level because there are fundamental differences between the approaches that are appropriate for* fluids stored, *as discussed in the Supporting Explanation to the definitions of these Categories above.*

J. Distinction between stored quantities and in SITU storage potential

52. *Other than quantities that are classified on the Feasibility axis as F4, all reported quantities shall be limited to those quantities that* can potentially be injected *on the basis of existing technology or technology currently under development, and are associated with actual or possible future* injection projects. *In the absence of any consideration of potential economic* injection, *all reported quantities shall be classified as F4.*

K. Aggregation of quantities

53. *Estimated quantities associated with* injection projects and geological storage *operations that are classified in different Categories on the Economic or Feasibility axis shall not be aggregated with each other without proper justification and disclosure of the methodology adopted. In all cases, the specific Classes that have been aggregated shall be disclosed in conjunction with the reported quantity (e.g. 111+112+221+222) and a footnote added to highlight the fact that there is a risk that Projects that are not classified as E1F1 (Commercial Projects) may not eventually achieve commercial operation.*

54. *Where estimated quantities have been aggregated from multiple projects, consideration should be given to sub-dividing the aggregated totals by* reservoir *and by location.*

L. Economic assumptions

55. *In accordance with the definitions of E1, E2 and E3, economic assumptions shall be based on current market conditions and realistic assumptions of future market conditions. Except where constrained by regulation, assumptions of future market conditions should reflect the view of either:*

(a) The organization responsible for the evaluation;

(b) The view of a competent person or independent evaluator; or,

(c) An externally published independent view, which is considered to be a reasonable forecast of future market conditions. The basis for the assumptions (as opposed to the actual forecast) shall be disclosed.

M. Evaluator qualifications

56. *Evaluators must possess an appropriate level of expertise and relevant experience in the estimation of quantities associated with the type of* reservoir *under evaluation.*

N. Units and conversion factors

57. *In order to facilitate global comparability of* storage estimates*, it is recommended that the Système International d'Unités (SI units) is used for reporting of resource quantities. However, it is recognized that there are traditional measurement units that are widely used and accepted for certain commodities; where such units are used for reporting purposes, conversion factors to SI units shall be provided. Similarly, where quantities are converted from one unit to another, the conversion factors applied shall be disclosed.*

O. Documentation

58. Estimated *quantities shall be documented in sufficient detail that would allow an independent evaluator or auditor to clearly understand the basis for estimation of the reported quantities and their classification.*

P. Expansion of G4 to account for uncertainty

59. *In some situations, it may be helpful to express a range of uncertainty for quantities that are classified on the Geological axis as G4, e.g.* Screening Projects*. In such cases, the following specification shall apply:*

(a) G4.1: low estimate of the quantities;

(b) G4.2: incremental amount to G4.1 such that G4.1+G4.2 equates to a best estimate of the quantities;

(c) G4.3: incremental amount to G4.1+G4.2 such that G4.1+G4.2+G4.3 equates to a high estimate of the quantities.

60. *Category G4, when used alone, shall reflect the best estimate and is equal to G4.1+G4.2.*

Q. Optional labels for estimates

61. *Where it is considered appropriate or helpful to use labels in addition to the numerical codes for a range of estimates for a specific* Injection Project*, the terms "Low Estimate", "Best Estimate" and "High Estimate" may be used to correspond to quantities that are classified on the Geological axis as G1, G1+G2 and G1+G2+G3 respectively.*

R. Classification of quantifies associated with screening projects

62. *In some situations, it may be helpful to sub-classify* Screening *Projects on the basis of their level of maturity. In such cases, the following specification shall apply:*

(a) F3.1: where site-specific geological studies and screening *activities have identified the potential for an individual* reservoir *with sufficient confidence to warrant drilling or testing that is designed to confirm the existence of that* reservoir *in such form,*

quality and quantity that the feasibility of injection and geological storage *can be evaluated;*

(b) F3.2: where local geological studies and screening *activities indicate the potential for one or more* reservoirs *in a specific part of a geological province, but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant drilling or testing that is designed to confirm the existence of a* reservoir *in such form, quality and quantity that the feasibility of* injection and geological storage *can be evaluated;*

(c) F3.3: at the earliest stage of exploration *activities, where favourable conditions for the potential discovery of* storage reservoirs *in a geological province may be inferred from regional geological studies.*

S. Classification of additional quantities available for geological storage

63. *In some situations, it may be helpful to sub-classify* projects where storage is currently not feasible (F4) *on the basis of the current state of technological developments. In such cases, the following specification shall apply:*

(a) F4.1: the technology necessary to store *some or all of the these quantities is currently under active development, following successful pilot studies on other* reservoirs, *but has yet to be demonstrated to be technically feasible for the style and nature of* reservoir in question;

(b) F4.2: the technology necessary to store *some or all of the these quantities is currently being researched, but no successful pilot studies have yet been completed;*

(c) F4.3: the technology necessary to store *some or all of these quantities is not currently under research or development.*

T. Quantities delivered for injection and storage that may not be stored

64. *The Sub-categories of E3 permit a distinction to be made between those quantities that may be available for* injection *but which* may not be stored due to for instance losses or leaks in the transportation or surface facilities *(E3.1) and those for which there are no reasonable prospects for economic* injection and geological storage *in the foreseeable future (E3.3).*

Annex I

Glossary of Terms[4]

Term	*Definition*
Aligned System	*A classification system that has been aligned with UNFC-2009 as demonstrated by the existence of a Bridging Document that has been endorsed by the Expert Group on Resource Classification.*
Bridging Document	*A document that explains the relationship between UNFC-2009 and another classification system, including instructions and guidelines on how to classify estimates generated by application of that system using the UNFC-2009 Numerical Codes.*
Category	*Primary basis for classification using each of the three fundamental Criteria of economic and social viability (related Categories being E1, E2, and E3), field project status and feasibility (related Categories being F1, F2, F3 and F4), and geological knowledge (related Categories being G1, G2, G3 and G4). Definitions of Categories are provided in Annex I to UNFC-2009.*
Class(es)	*Primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes).*
Complementary Texts	*Additional texts to provide mandatory requirements (i.e. Specifications) and further guidance regarding the application of UNFC-2009. (This Specifications Document is an example of a complementary text.)*
CRIRSCO Template	*The CRIRSCO Template of 2013 is the system developed by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) for solid minerals and, for the purposes of this Specifications Document, includes the reporting codes and standards that are aligned with it.*
Criteria	*UNFC-2009 utilizes three fundamental Criteria for reserve and resource classification: economic and social viability; field project status and feasibility; and, geological knowledge. These Criteria are each subdivided into Categories and Sub-categories, which are then combined in the form of Classes or Sub-classes.*

[4] Additional terms are added to the Glossary of Terms included in Annex I of Part II of "UNFC-2009 incorporating Specifications for its Application" (ECE Energy Series No. 42 and ECE/ENERGY/94) where deemed necessary for the application of UNFC-2009 to injection projects for the purpose of geological storage. The original text is shown in italics and the additional terms for the application of UNFC-2009 to injection projects for the purpose of geological storage are shown as underlined text.

Term	*Definition*
Evaluator	*Person, or persons, performing resource estimation and/or classification.*
Exploration Projects	*A Project that is associated with one or more Potential Deposits (as defined below).*
Generic Specifications	*Specifications (as documented in this Specifications Document) that apply to the classification of quantities of any commodity using UNFC-2009.*
Known Deposit	*A deposit that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant commodity-specific Aligned Systems.*
Mapping Document	*The output of a comparison between another resource classification system and UNFC-2009, or between that system and existing Aligned Systems, which highlights the similarities and differences between the systems. A Mapping Document can provide the basis for assessing the potential for the other system to become an Aligned System through the development of a Bridging Document.*
Numerical Code	*Numerical designation of each Class or Sub-class of resource quantity as defined by UNFC-2009. Numerical Codes are always quoted in the same sequence (i.e. E;F;G).*
Porosity	The ratio of the aggregated volume of interstices in a rock to its volume. Usually stated as a percentage.
Potential Deposit	*A deposit that has not yet been demonstrated to exist by direct evidence (e.g. drilling and/or sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. surface or airborne geophysical measurements). More detailed specifications can be found in relevant commodity-specific Aligned Systems.*
Potential Reservoir	A reservoir that has not yet been demonstrated to exist by direct evidence (e.g. drilling and/or sampling), but is assessed as potentially existing based primarily on indirect evidence (e.g. surface or airborne geophysical measurements).
PRMS	*Petroleum Resources Management System of 2007 (PRMS), which was approved by the Society of Petroleum Engineers (SPE) Board in March 2007 and endorsed by the World Petroleum Council (WPC), the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Evaluation Engineers (SPEE) and the Society of Exploration Geophysicists (SEG).*

Project	*A Project is a defined development or mining operation which provides the basis for economic evaluation and decision-making. In the early stages of evaluation, including exploration, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail. Where no development or mining operation* or injection project *can currently be defined for all or part of a deposit* or reservoir, *based on existing technology or technology currently under development, all quantities associated with that deposit* or reservoir *(or part thereof) are classified in Category F4.*
Reservoir	A subsurface body of rock with sufficient porosity and permeability to store and transmit fluids.
Specifications	*Additional details (mandatory rules) as to how a resource classification system is to be applied, supplementing the framework definitions of that system. Generic Specifications provided for the UNFC-2009 in this Specifications Document ensure clarity and comparability and are complementary to the commodity-specific requirements included in Aligned Systems, as set out in the relevant Bridging Document.*
Specifications Document	*Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009).*
Sub-categories	*Optional subdivision of Categories for each of the fundamental Criteria of economic and social viability, field project status and feasibility, and geological knowledge. Definitions of Sub-categories are provided in Annex II to UNFC-2009.*
Sub-classes	*Optional subdivision of resource classification based on project maturity principles resulting from the combination of Subcategories. Project maturity Sub-classes are discussed further in Annex V of the UNFC-2009 Specifications Document.*
Système International d'Unités	*Internationally recognized system of measurement and the modern form of the metric system. Prefixes and units are created and unit definitions are modified through international agreement as the technology of measurement progresses, and as the precision of measurements improves. Abbreviated to SI.*
UNFC-2009	*United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009.*

United Nations ECE/ENERGY/GE.3/2015/5

Economic and Social Council

Distr.: General
20 February 2015

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Fifth session
Geneva, 28 April – 1 May 2015
Item 15 of the provisional agenda
Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Norwegian Petroleum Directorate 2014 Case Study: The 2013 Norwegian Petroleum Resource Accounts presented according to UNFC-2009

Prepared by Kjell Reidar Knudsen, Senior Adviser, Norwegian Petroleum Directorate*

* Co-authors from the Norwegian Petroleum Directorate are Tom Andersen, Marit Arnesen, Per Blystad and Magnar Haugvaldstad.

GE.15-02995 (E)

1502995

Please recycle

I. Introduction

1. One of the Norwegian Petroleum Directorate's (NPD) most important tasks is to maintain an overview of all of the petroleum resources on the Norwegian continental shelf.

2. The objective is to ensure that the resources are managed in the best interests of the Norwegian society.

3. The NPD collects and analyses data from the companies operating on the Norwegian continental shelf and compares this with the NPD's own data and forecasts. This information is an important management tool for the oil sector, and provides fundamental terms for developing the Government's budgets and oil policies.

4. Comprehensive, updated information and facts about the petroleum activities in Norway is available on the NPD's website[1], including various reports, fact-pages and fact-maps, etc.

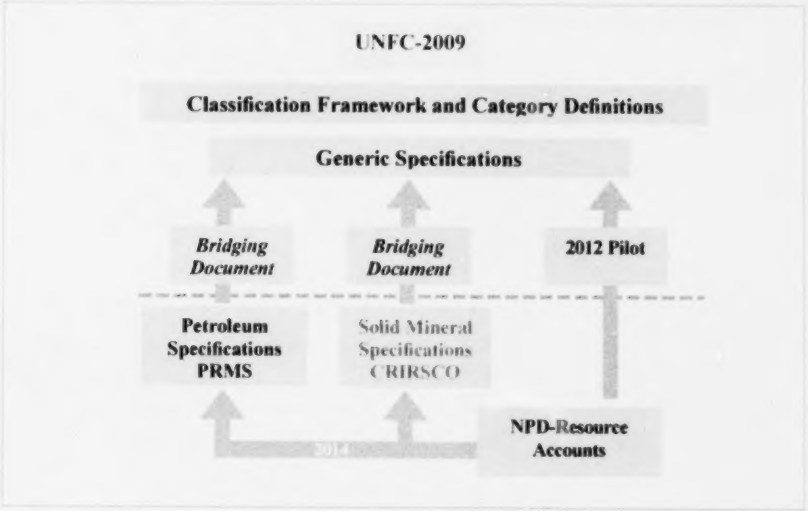
5. The NPD has been involved in the process of developing the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) since 2001. Firstly, as a member of the Ad Hoc Group of Experts on the Harmonization of Fossil Energy and Mineral Resources Terminology) and then subsequently in the Bureau of the Ad Hoc Group of Experts, the leader of the Petroleum Group, the co-leader of the Mapping Task Force, a member of the Specification Task Force Phase One, a member of the Expert Group on Resource Classification, a member of the Bureau of the Expert Group, a member of the Specification Task Force Phase Two, and most recently a member of the Technical Advisory Group. In all of these committees, the NPD has discussed definitions and terminology, representing the Government Resource Management stakeholder group.

6. This paper describes how the NPD has, in practical terms, used UNFC-2009 on the full portfolio of petroleum resources in Norway. In addition the paper also explains how the Pilot Study in 2012 was carried out. Direct mapping between the NPD classification and UNFC-2009 requires that a Bridging Document, explaining the connections between the two systems, is developed and consented to by the Expert Group on Resource Classification (or Technical Advisory Group). Since such a Bridging Document has not yet been established, the mapping of the Norwegian Resource Accounts for 2013 to UNFC-2009 has been carried out using the Bridging Document between the Petroleum Resource Management System (PRMS) endorsed by the Society of Petroleum Engineers (SPE) Board in March 2007 and endorsed by the World Petroleum Council (WPC), the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Evaluation Engineers (SPEE) and the Society of Exploration Geophysicists (SEG) and UNFC-2009, included as Annex IV in ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application". The mapping through the use of this Bridging Document is the focus of this case study.

7. Figure 1 illustrates how the 2012 Pilot Study mapped the Norwegian numbers directly to the UNFC-2009 definitions and supporting explanations, while the conversion of the 2013 accounts undertaken in the 2014 Case Study was carried out using the UNFC-2009 Generic Specifications and the PRMS Bridging Document.

[1] http://www.npd.no/

Figure 1.
2012 Pilot study and 2014 case study mapping



II. The Norwegian Resource Classification System

8. Figures 2 and 3 show two ways of presenting the Norwegian Resource Classification System.

9. The system is "project based", which means that each project is classified in one of the categories. The three classes are the undiscovered resources, contingent resources and reserves. Each class consists of several categories. The names of the categories reflect the maturation of the projects:

(a) Undiscovered resources in Resource categories 8 and 9;

(b) Both new discoveries and possible future measures for improved oil recovery (IOR) which have not yet been evaluated in Resource category 7;

(c) Projects where recovery is not very likely in Resource category 6;

(d) Unclarified projects in Resource category 5;

(e) Projects in the planning phase in Resource category 4;

(f) Projects decided for development in Resource category 3;

(g) Approved development projects in Resource category 2;

(h) Producing projects in Resource category 1.

10. One of the requirements for the NPD Resource Classification System is that it should allow for the possibility of classifying and tracking the maturation of increased recovery projects. Therefore each Resource category, as illustrated here, has two attributes, the F-attribute for "First" and the A-attribute for "Additional" recoverable quantities that are coming from the same original oil and gas in place.

Figure 2.
The traditional way of presenting the Norwegian Classification System

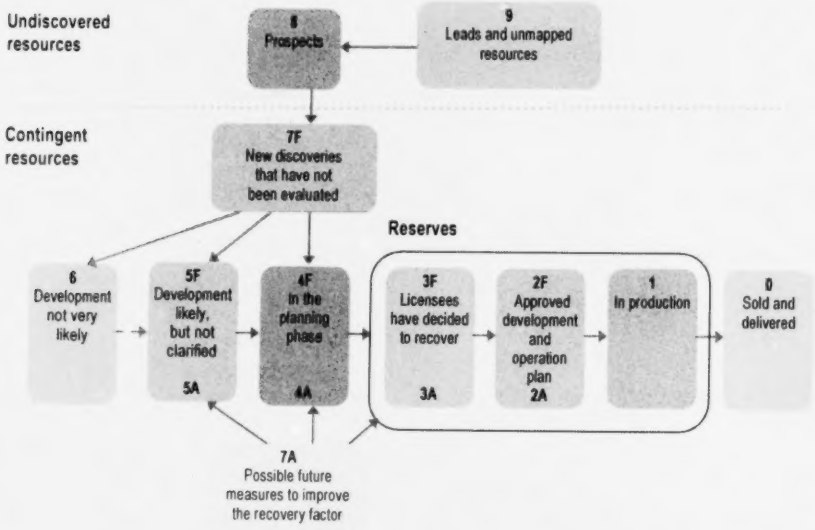


Figure 3.
The Norwegian Classification System

	NPD 2001			*Class*
		Category		
Discovered	Reserves	In production	1	Reserves
		Approved Plan for Development and Operation (PDO)	2F	
			2A	
		Licensees decided to recover	3F	
			3A	
	Contingent Resources	In the planning phase	4F	Contingent Resources
			4A	
		Recovery likely but undecided	5F	
			5A	
		Not yet evaluated additional potential	7A	
		Not yet evaluated	7F	
		Recovery not very likely		
Undis-covered	Undiscovered Resources	Prospect	8	Undiscovered resources
		Lead and Play	9	

11. The Norwegian Classification System requires that all resource estimates must describe a low estimate, a base estimate and a high estimate.

12. The low estimate must be lower than the base estimate. The probability of being able to recover the stated estimate or more must be stated (e.g. P90 or P80). Unlike the base estimate, the low estimate should be an expression of possible negative changes with respect to the mapping of the reservoir, reservoir parameters, or the recovery factor.

13. The base estimate must reflect the current understanding of the extension, characteristics and recovery factor of the reservoir. The base estimate will be calculated deterministically or stochastically. If the base estimate is calculated using a stochastic method, it must correspond to the mean value.

14. The high estimate must be higher than the base estimate. The probability of being able to recover the stated estimate or in excess of this must be stated (e.g. P10 or P20). Unlike the base estimate, the high estimate must be an expression of possible positive changes with respect to the mapping of the reservoir, reservoir parameters, or the recovery factor.

15. In comparing the Norwegian system to UNFC-2009, it is noticed that the G-axis of UNFC-2009 corresponds to the NPD definitions of Low, Base and High estimates. See figure 4.

16. If calculations are done by a stochastic method, the NPD system offers some flexibility for choosing which levels of confidence to use, but reporting guidelines recommend P90 (low), P50 (mean) and P10 (high). These levels of confidence are supposed to reflect all uncertainties; either they are of geological or technical reasons.

17. In the NPD system, the same "High", "Base" and "Low" labels are also used for undiscovered resources whilst in UNFC-2009, volume estimates of undiscovered resources are all represented in G4. However, in the Generic Specifications there is an option to create sub-classes of this, to represent different confidence levels of the estimates.

Figure 4.

Comparing the Norwegian classification system to UNFC-2009

Discovered resource		G1	Low estimate
		G1+G2 (Best estimate)	Base estimate
		G1+G2+G3	High estimate
		G4	Base estimate
Undiscovered resources	UNFC-2009 Generic Specification P[a]	G4.1	Low estimate
		G4.1+G4.2 (Best estimate)	Base estimate
		G4.1+G4.2+G4.3	High estimate

[a] Expansion of G4 to account for uncertainty

III. The 2012 Pilot Study

18. The alignment of the NPD resource category estimates to a UNFC-2009 class estimate for the 2012 Pilot Study was done in two different ways:

(a) On a one-to-one basis: this is illustrated by the green boxes in figure 5. This was called "The General rules categorization method". The total aggregated volumes of each NPD Resource Category were mapped to only one UNFC-2009 Sub-category.

(b) On a specific project basis: this approach required that more information on each project than the general information described by the Resource Category definitions

was considered for each individual project. As a result the estimate for some projects could also end up in the white boxes shown in figure 5.

19. Projects classified as Reserves in the Norwegian system, were mapped quite easily, as there were no alternatives. The estimates for all projects in one NPD Status Category go straight into the corresponding UNFC-2009 Sub-class. Hence, the mapping of the Commercial Project's Sub-classes was easily done.

20. However, for the "Contingent resources" additional sub-classes had to be considered in classifying the projects – i.e. some of the white boxes were used (See figure 5).

Figure 5.

Mapping to UNFC-2009

NPD Classes	*NPD Category*	*UNFC Sub-classes*
Reserves	1	E1.1F1.1
	2 F	E1.1F1.2
	2 A	E1.1F1.2
	3 F	E1.1F1.3
	3 A	E1.1F1.3
Contingent Resources	4 F	E1.1F2.1
		E2F2.1
		E1.1F2.2
	4 A	E1.1F2.1
		E1.1F2.2
		E2F2.1
		E2F2.2
	5 F	E1.1F2.1
		E2F2.1
		E1.1F2.2
		E2F2.2
		E3.2F2.2
	5 A	E1.1F2.1
		E2F2.1
		E1.1F2.2
		E2F2.2
	6	E3.3F2.3
	7 F	E2F2.1
		E2F2.3
		E3.2F2.1
		E3.2F2.2
		E3.2F3
	7 A	E2.F2.1
		E2,F2.2
		E3.2F2.2
		E3.2F3

Undiscovered Resources	**8**	**E3F3G4**
	9	**E3.2F3**

21. Table 1, from the 2012 Pilot Study, compared the results from taking the Norwegian resource estimates into UNFC-2009 by the two different methods just explained:

- Mapping of classes and sub-classes from the two systems by "General rules categorization method"; and
- Direct classification on an individual project basis.

22. Representation of the mapping at aggregated level through classes, shows only very minor differences between the two methods. For the classes of Commercial Projects and Exploration Projects the results are identical. The difference is seen in the Potential Commercial Projects Class and in the Non-Commercial Projects Class. Assuming that the Individual Project mapping is the correct mapping, the results from the general rules categorization differs by only four per cent for the Potentially Commercial Projects and by two per cent for the Non-Commercial Projects.

23. Presenting the mapping at the sub-class level shows larger differences between the two methods, as also shown in Table 1. This is to be expected, as the general rules categorization assumes that there are only one-to-one relationships between the sub-classes of the two classifications. Detailed mapping by projects demonstrate that in several cases one-to-many relationship exists, but only within the classes.

24. The summary of the 2012 Pilot Study presentation was:

- The differences between individual project classification and class mapping results are minor;
- This demonstrates that the mapping between the NPD system and UNFC-2009 was acceptable as a Pilot.

Table 1.

Results from the 2012 Pilot Study: Detailed mapping results (Norwegian Resource Accounts per 31 December 2011)

	Sub-classes				***Classes***	
UNFC-2009 Sub-class	*General rules categorization*	*Project individual categorization*	G1 + G2 Mill scm oil equivalent	*UNFC-2009 Sub-class*	*General rules categorization*	*Project individual categorization*
E1.1F1.1	2 347	2 347		E1F1	3 164	3 164
E1.1F1.2	433	433		E1F2	593	571
E1.1F1.3	384	384		E1F3	0	0
E1.1F2.1	593	432		E2F1	0	0
E1.1F2.2	0	139		E2F2	988	1 012
E2F2.1	798	728		E2F3	0	0
E2F2.2	190	284		E3F1	0	0
E3.2F2.1	182	181		E3F2	182	181
E3.2F3G4	2 455	2 455		E3F3	0	0
E3.3F2.3	0	0		E3F3G4	2 455	2 455
Total	**7 382**	**7 382**		**Total**	**7 382**	**7 382**

IV. 2014 Case Study

25. Up to 2012, only UNFC-2009 definitions and the concepts were available and approved, and discussions took place on how to use the concept on real cases for the various commodities. The NPD 2012 Pilot Study provided useful input.

26. In December 2013, the UNFC-2009 Generic Specifications were completed. The ECE ENERGY SERIES No. 42 includes Generic Specifications and approved Bridging Documents between PRMS and UNFC-2009 for petroleum and between the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template and UNFC-2009 for solid minerals.

27. The UNFC-2009 specifications require that when mapping other classification system to UNFC-2009, the relationship between the two systems must be documented in a Bridging Document which has been endorsed by the Expert Group on Resource Classification or by using an existing aligned system. So far only the PRMS is aligned for petroleum.

V. The Norwegian Petroleum Resource Accounts mapped to UNFC-2009

28. The Norwegian Petroleum Resource Accounts, as of 31 December 2013, are a comprehensive compilation of information from more than 800 projects, all of which are classified individually. Most of the projects are reported by the operating companies through the annual reporting in connection with the Revised National Budget reporting. The project aims to present the NPD resource account in the form of UNFC-2009.

29. The classification of each project according to the Norwegian System is discussed with the operating oil companies every year, during a process of establishing an inventory of all projects that the companies have to report to NPD, prior to the actual reporting. This inventory, or "project list" is a list of all projects with name and resource category. This is an iterative process, sending information back and forth. There is not always agreement, but in most cases the companies' opinion and the NPD's opinion regarding which category a project belongs to is the same. This is always carried out before the reporting deadline.

30. As part of the process of reporting the resource figures by the deadline, additional project information is made available to the NPD upon request. Examples of this are the so called "project stopper attributes" which will be explained later.

VI. Mapping estimates to UNFC-2009 by using the PRMS Bridging Document

31. The following hierarchy of instructions were used when mapping the Norwegian Resource Accounts to UNFC-2009 in 2014.

UNFC-2009 Definitions (Part I)

UNFC-2009 Specifications (Part II)

IV. National Resource Reporting

VI. Generic Specifications

B. Requirement of a Bridging Document

Annex IV. Bridging Document from PRMS

32. The first step was to map the Norwegian system to the PRMS. This was, in practical terms, quite simple. According to the definitions and specifications of the two systems, there is a "reasonable" one-to-one relationship between the two:

(a) A project in Norwegian RK1 will be classified in the category "On production" in PRMS (and given the code 1 in the Bridging Document).

(b) A project in Norwegian RK2 will be classified in the category "Approved for development" in PRMS (and given the code 2 in the Bridging Document).

(c) A project in Norwegian RK3 will be classified in the category "Justified for development" in PRMS (and given the code 3 in the Bridging Document).

(d) A project in Norwegian RK4 will be classified in the category "Development pending" in PRMS (and given the code 4 in the Bridging Document) even if the definitions in the two systems are somewhat different. Some of the RK4 projects could also be defined as "Development on hold". However, this ambiguous "general rule categorization" is compensated in the last step when allocating specific UNFC-2009 Sub-classes to individual projects where the PRMS-mapping allow for alternative "routes".

(e) A project in Norwegian RK5 will be classified in the category "Development on hold" in PRMS (and given code 5 in the Bridging Document), even if the definitions in the two systems are different. Some of the RK5 projects, it could be argued, belong to "Development Pending". However, to avoid being too progressive, this was not done for the 2014 case study.

(f) A project in Norwegian RK6 will be classified in the category "Development not viable" in PRMS (and given the code 7 in the Bridging Document).

(g) It should be noted that both the Norwegian RK 7F and RK 7A will end up in "Development unclarified" (and given the code 6 in the Bridging Document). See table 2.

Table 2.
Step 1: Bridge from the Norwegian system to PRMS

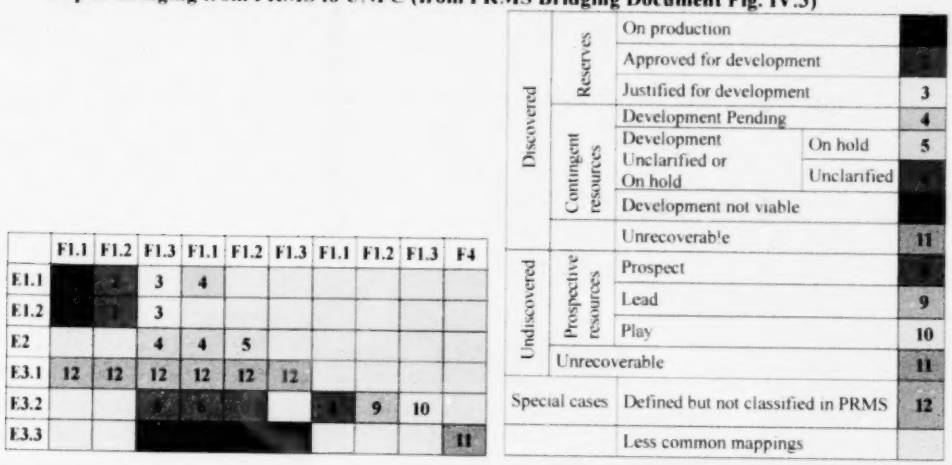
	NPD Category				*PRMS*		*PRMS Bridging*
	Class	*Sub-class*	*Main*	*Sub*			
Project A	Reserve	In production		F+A	Reserve		
Project B	Reserve	Approved for development	RK2	F	Reserve	Approved for development	2
Project C	Reserve	Approved for development		A			
Project D	Reserve	Decided for development	RK3	F	Reserve	Justified for development	3
Project E	Reserve	Decided for development		A			
Project F	Contingent Resource	In planning phase	RK4	F	Contingent Resource	Development pending	4
Project G	Contingent Resource	In planning phase		A			
Project H	Contingent Resource	Recovery Likely, but undecided	RK5	F	Contingent Resource	Development on hold	5
Project I	Contingent Resource	Recovery Likely, but undecided		A			
Project J	Contingent Resource	Not evaluated/ Improved rec pot		F	Contingent Resource		
Project k	Contingent Resource	Not evaluated/ Improved rec pot		A			
Project L	Contingent Resource	Recovery not very likely	RK6	F+A	Development not viable	Development not viable	7
Project M	Undiscovered	Prospect			Prospective Resources		
						Lead	9
Project O	Undiscovered	Lead and play	RK9			Play	10
					Specified but not classified		12

33. Step two is to look at how the PRMS classes are mapped to UNFC-2009: this is very well described in the Bridging Document between PRMS and UNFC-2009 (See figure 6).

34. Figure 6 shows how each PRMS Project Maturity Sub-class is mapped along the E- F Matrix, using the UNFC-2009 Sub-categories.

Figure 6.

Step 2: Bridging from PRMS to UNFC (from PRMS Bridging Document Fig. IV.3)



35. Step three is to replace the UNFC-2009 codes with the Norwegian Resource categories (figure 7). It should be noted that there are several alternatives. The challenge is where to put each of the project estimates.

36. This challenge is also commented on in the Bridging Document, Chapter IV, B. However, there is no guidance on how to deal with this, except by referring to the UNFC-2009 Sub-category definitions themselves.

Figure 7.

Norwegian resource category codes inserted (PRMS colour codes used)

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4
E1.1		RK2	RK3	RK4						
E1.2		RK2	RK3							
E2			RK4	RK4	RK5					
E3.1										
E3.2			RK7	RK7	RK7				RK9	
E3.3										

37. Fortunately the challenge is now reduced due to the fact that some combinations are not possible according to the Norwegian situation and the Norwegian specifications:

(a) No subsidized projects exist (e.g. all E1.2 boxes are not used);

(b) No RK4 projects fulfil F1.3 definition because it is not expected that very detailed studies have been undertaken before the decision to deliver a Plan for Development and Operation (PDO) has been taken;

(c) No RK7 projects should be classified higher than F2.2 (e.g. F2.1), because these projects will normally be less mature than the RK5 projects which are classified in category F2.2;

(d) The Bridging Document code 12, non-sales production, is not classified in the NPD system, as in PRMS.

38. Figure 8 illustrates which alternatives still exist: two boxes for RK4, two boxes for RK8, one box for RK9 and four boxes for RK6.

Figure 8.

Intermediate mapping of NPD project categories to the E-F Matrix by use of the PRMS Bridging Document

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4
E1.1		RK2	RK3	RK4						
E1.2										
E2				RK4	RK5					
E3.1										
E3.2					RK7				RK9	
E3.3										

39. In order to proceed, the following solution was found: RK4 projects required more information on each individual project. RK8 and RK9 were combined in the "Main" F3 class, and all RK6 estimates were put in the "least valuable box" which is E3.3,F2.3 ("least valuable principle") . This is illustrated in figure 9.

Figure 9.

Final mapping of NPD project categories to the E-F Matrix by use of the PRMS Bridging Document

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4
E1.1		RK2	RK3	RK4						
E1.2										
E2				RK4	RK5					
E3.1										
E3.2					RK7					
E3.3										

40. The last challenge left was how all the RK4 projects should be sorted as there were two possible alternatives. In the end, the same approach as that taken in the 2012 Pilot Study was used. Each project with one of the following "project stoppers": "Technology lacking", "Lack of infrastructure", "No gas solution" or "No commercial agreement" was downgraded on the E- and/or F-axis as shown below.

41. Based on this information, projects were moved from E1.1 to E2.1 as follows:

- Technology is lacking
    - RK4A (two projects from E1.1F2.1 to E2F2.1)
- Lack of infrastructure in the area
    - RK4F (two projects from E1.1F2.1 to E2F2.1)
    - RK4A (two projects from E1.1F2.1 to E2F2.1)
- No gas solution
    - RK4F (one project from E1.1F2.1 to E2F2.1)
- No commercial agreement

- RK4F (eight projects from E1.1F2.1 to E2F2.1)
- RK4A (move from E1.1F2.1 to E2F2.1).

42. Once the detailed mapping of all the projects into one specific UNFC-2009 Sub-class was completed, the G1+G2 estimates (mean value) for all the 800 projects were aggregated. Table 3 shows the aggregated values, both at a Sub-class and at a Class level.

Table 3.

The results from the 800 projects for G1 + G2 (mean value) presented for UNFC-2009 Sub-Classes and Classes

UNFC-2009 Sub-class	*Oil mill scm*	*NGL mill tonne*	*Conden-sate mill scm*	*Gas bill scm*	*Oil equivalent mill scm*
1.1.1.1+2	599	104	30	1437	2263
1.1.1.2.1+	224	15	6	217	474
1.1.1.3.1+	12	10	4	395	430
1.1.2.1.1+2	606	15	2	112	747
2.2.1.1+2	40	3	2	43	92
2.2.2.1+2	247	17	7	263	550
3.2.2.2.1+	278	1	12	186	478
3.3.2.1+2	0	0	0	0	0
3.2.3.4	1330	0	120	1490	2940

UNFC-2009 Class	*Oil mill scm*	*NGL mill tonne*	*Conden-sate mill scm*	*Gas bill scm*	*Oil equivalent mill scm*
1.1.1+2	835	129	40	2049	3167
1.2.1+2	606	15	2	112	747
2.2.1+2	287	20	9	306	642
3.2.1+2	278	1	12	186	478
3.3.4	1330	0	120	1490	2940

Note:
Standard cubic metre oil equivalent (scm oe) is calculated so that:
1 scm of oil = 1 scm oe
1 scm of condensate = 1 scm oe
1 000 scm of gas = 1 scm oe
1 tonne of NGL = 1.9 scm NGL = 1.9 scm oe

VII. How G1 and G3 were calculated

43. The table (figure 10) of total resources with uncertainty (i.e. with G1 and G1+G2+G3 included) had to be constructed in two steps in order to achieve plausible results.

44. First, all G1, G1+G2 and G1+G2+G3 estimates for all projects were aggregated together using a stochastic aggregation tool. Dependencies between projects internally in each sub-class were included. This is called "envelope".

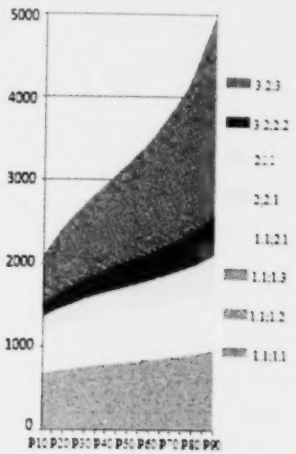
45. Thereafter all G1, G1+G2 and G1+G2+G3 estimates for all projects in each sub-class were aggregated together using a stochastic aggregation tool. The value of the high and low estimates for the Sub-classes was then adjusted proportionally to fit into the envelope. Figure 10 shows how the G-axis was used to illustrate the uncertainty of the resource accounts. It also shows how the "Examples of classes" in Figure 1 in UNFC-2009 fits to the Classes and Sub-classes used by NPD. The figure also demonstrates that other Sub-classes than the coloured ones (which have been given "labels") have been used. See Chapter IV Sub-classes (page 8 in the ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application) for information on how additional Sub-classes might be used.

46. An illustration of the distribution, similar to the one that NPD is presenting in its resource accounts (the "ski jump"), is also included figure 10.

Figure 10.

The Norwegian Petroleum Resource Accounts as of 31 December 2013 mapped to UNFC-2009

UNFC-2009 Class	*Oil mill scm*	*Oil mill scm*	*Oil mill scm*	*UNFC-2009 examples of classes with "labels"*
	G1	G1+G2	G1+G2+G3	
E1.1.F1.1	485	599	693	Commercial projects
E1.1.F1.2	182	224	264	
E1.1.F1.3	10	12	13	
E1.1. F 2.1	482	606	735	
E2.F2.1	28	40	54	Potential commercial projects
E2.F2.2	161	247	348	
E3.2.F2.2	170	278	485	
E3.3.F2	0	0	0	
	G4.1	G4.1+G4.2	G4.1+G4.2+G4.3	
E3.2.F3	588	1330	2442	Exploration projects



VIII. Summary

47. As a conclusion of this study, the following points are noted:

(a) It is feasible to present and communicate the NPD Annual Petroleum Resource Accounts by using UNFC-2009;

(b) Converting older historic Resource Accounts to UNFC-2009 cannot be undertaken based on classified project categories alone. Since more information than that which is provided by the Norwegian Resource Categories alone is required for classifying some projects, a more detailed study of all individual project attributes as reported at that time would be necessary;

(c) The differences between the NPD F and A attributes are not visible unless new Sub-categories are defined in UNFC-2009 (see ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Generic Specification A 'Use of numerical codes', last paragraph);

(d) The "least valuable principle" was used when it is not possible to separate detailed information between Sub-classes;

(e) UNFC-2009's ability to use more granularity than the example Classes shown in figure 1 in the ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application" is useful;

(f) There are a number of practical "challenges" in handling the G1 and G3 for a portfolio, as aggregation should be done by the stochastic method. Dependencies between the projects have to be taken into consideration.

United Nations ECE/ENERGY/GE.3/2015/5/Corr.1

Economic and Social Council

Distr.: General
18 March 2015

Original: English
English and French only

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Fifth session
Geneva, 28 April – 1 May 2015
Item 15 of the provisional agenda
Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Norwegian Petroleum Directorate 2014 Case Study: The 2013 Norwegian Petroleum Resource Accounts presented according to UNFC-2009

Note by the secretariat

Corrigendum

The corrections to Section VI should read as follows:

Page 11, Paragraph 34. Figure 6.

For Header Row:

	F1.1	F1.2	F1.3	F1.1	F1.2	F1.3	F1.1	F1.2	F1.3	F4

Read Header row:

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4

GE.15-05834 (E)
1505834

Please recycle

United Nations ECE/ENERGY/GE.3/2015/6

Economic and Social Council

Distr.: General
16 February 2015

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Sixth session
Geneva, 28 April – 1 May 2015
Item 15 of the provisional agenda
Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case Study – A thorium source in the Mountain Pass rare earth elements deposit, California, United States, and the application of UNFC-2009

Prepared by Bradley S. Van Gosen, United States Geological Survey (USGS)

I. Introduction

1. Historically, uranium and thorium deposits worldwide have been classified and reported according to the resource reporting scheme developed by the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA) and the International Atomic Energy Agency (IAEA). This system consists of a biaxial classification that considers the degree of geological knowledge and the production costs of uranium concentrate and (where applicable) thorium concentrate.

2. Thorium, similar to uranium, can be utilized as a nuclear fuel. Despite numerous projects and several pilot test reactors in several countries designed to evaluate thorium as a viable reactor fuel, thorium-based nuclear power has yet to be fully commercialized. Currently, research and development is being carried out on several concepts for advanced reactors including: high-temperature gas-cooled reactors (HTGR); molten salt reactors (MSR); Canada Deuterium Uranium (CANDU)-type reactors; advanced heavy water

GE.15-02992 (E)

1502992

Please recycle

reactors (AHWR); and fast breeder reactors (FBR). Federal government-supported projects, particularly in India and China, are focused on the development of thorium-based nuclear power [1]. Based on these activities, utilization of thorium as a fuel is expected after 2020.

II. Background

3. Because of the low demand for thorium, it has not been a primary target of exploration in the past. The research and development efforts mentioned above may increase the demands for thorium and likewise increase national and global evaluations of thorium deposits.

4. Mineral deposits that are rich in the rare earth elements (REEs) typically also contain anomalous enrichments in thorium. Primarily for this reason, the most likely sources of thorium in the foreseeable future will come from the recovery of thorium as a co-product of the mining and processing of REE deposits.

5. Production of REEs during the 1950s to the late 1980s came primarily from the United States, India, South Africa and Brazil. In 1927, Chinese geologists discovered REE deposits at Bayan Obo in the Inner Mongolia Autonomous Region. Mines and processing plants built at Bayan Obo began to produce REE concentrates in 1957 [2]. By 2002, China became the dominant producer of REEs in the world [2]. During the more than 80 years following the discovery of Bayan Obo, REE deposits were found in 21 of China's Provinces and Autonomous Regions [2]. In 2009, China reported its domestic extractable quantities of REEs as 18.6 million metric tons (tonnes) of REE oxide [3, p. 410]. China introduced a production quota on its REE industry in 2008 [2], which triggered a worldwide search for REE deposits in other countries. In recent years, deposits of REE resources have been assessed in Australia, Brazil, Canada, China, Finland, Greenland, India, Kyrgyzstan, Madagascar, Malawi, Mozambique, South Africa, Sweden, Tanzania, Turkey, the United States, and Vietnam [4, 5, 6].

6. Actively mined REE ore deposits are economic on the basis of their REE production. Co-existing thorium-rich minerals could be evaluated as sources of by-product or co-product thorium if a market develops for thorium in the future. For now, the production of thorium as the primary product is thought to be uneconomic [1]. In the context of production, a by-product can be defined as the "output from a joint production process that is minor in quantity and/or net realizable value (NVR) when compared to the main products" [7]. By convention, by-products also are not inventoried, but the NRV from by-products is typically recognized as 'other income' or as a reduction of joint production processing costs when the by-product is produced. Co-product on the other hand is a major output from a joint production process that is significant in quantity and/or NVR. Co-products play an important role in the economic analysis of a mineral project.

7. In most REE-thorium-rich deposits, the most common thorium-bearing mineral is monazite, an REE–thorium–phosphate mineral. Thus, most of the thorium content in the majority of REE deposits is due to monazite and only occasionally due to other thorium-rich minerals, such as thorite (thorium silicate). Monazite can contain as much as 20 per cent thorium oxide [8]; hence, thorium may be evaluated as a co-product in many REE deposits containing monazite.

8. Moreover, policy objectives of waste hierarchy, such as the European Union Waste Framework Directive (established in 1975), mandate disposal as the last and least desirable of the management options of any process residues [9, 10]. Reuse, recycling, energy recovery, and other potential uses are to be considered before materials are assigned as waste and presumptively disposed.

9. Monazite concentrate production is currently taking place in India, Malaysia, Vietnam, and Brazil, in decreasing order of production [4]. The Indian Bureau of Mines describes India's coordinated effort to recover monazite from heavy-mineral sands then chemically treat the monazite to separate rare earths in composite chloride form and thorium as hydroxide upgrade [11]. The planned capacity of the monazite processing plant was established at 10,000 tonnes per year in 2011, expected to be increased to 20,000 tonnes per year in the future [11]. The recovery of thorium from monazite-rich ore is being considered for the Steenkampskraal deposit in South Africa, which is an REE mining and production project under development in 2014 [12, 13].

10. The co-product occurrence of thorium and a general lack of economic interest in thorium have meant that thorium quantities were rarely, if ever, accurately defined in most countries. Information on estimated quantities of thorium was published between 1965 and 1981 in the biennial publication the "Red Book", published jointly by the NEA and IAEA; the thorium estimates reported in these reports applied the same terminology as was used for uranium resources at that time. The "Red Book" is the informal, commonly used name for a biennial report prepared jointly by the NEA and IAEA [1], which provides the most recent overview of the world uranium market fundamentals and industry, including uranium exploration, resources, production, and projected reactor-related requirements.

11. In 2012, the United States reported identified domestic thorium quantities (in situ) of about 434,000 tonnes of thorium [1]. The principal thorium deposit types in the United States are vein-type, carbonatite-hosted, and placers [14].

III. The Case Study

12. The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) allows the documentation and reporting of estimated known, inferred, and undiscovered thorium quantities. The UNFC-2009 classification scheme, in addition to providing the project maturity of mineral commodities, considers social and economic issues, including regulatory, legal and market conditions imposed by governments and markets, domestic demand, technological and industrial progress, as well as ever-present uncertainty of the foreseeable future.

13. This case study presented here is a UNFC-2009 classification of a REE-thorium deposit in California, United States, classifying the deposit as both a source of REEs and as a potential source of thorium. Specifically, the deposit used in this example is the REE ore body developed by the Mountain Pass mine in southeast California, owned and operated by Molycorp Inc.[1] (Figure 1). The mine and onsite mineral processing plants exploit the largest known REE deposit in the United States—the Sulphide Queen carbonatite [15]. After an eight-year hiatus, Molycorp reopened operations at the mine in late 2010. The mining and ore-processing operations at Mountain Pass remain active at this time (2014).

14. The REE ore body of Mountain Pass represents a potential future source of thorium as a co-product of REE production. The thorium content in this ore body is primarily due to the mineral monazite, which is intimately intergrown with the REE ore minerals. Monazite concentrations range throughout the ore body from trace amounts to locally abundant [15].

15. Molycorp Inc. reports that the Mountain Pass ore body—the Sulphide Queen carbonatite—contains Proven and Probable Reserves of 16.7 million tonnes of ore with an average grade of 7.98 per cent REE oxides, applying a cut-off grade of 5 per cent REE oxides [16]. A recent United States Geological Survey reconnaissance bulk sampling of ore

[1] http://www.molycorp.com/

exposed in the open-pit mine (about one tonne of composited ore was collected) found an average thorium content of approximately 0.025 per cent within high-grade REE ore; this value is nearly identical to the thorium concentrations found in earlier geochemical studies of this carbonatite [17]. This thorium concentration suggests that each tonne of ore mined from the deposit contains on average approximately 0.25 kilogrammes of thorium. This estimate of thorium content in the Sulphide Queen orebody is certainly an approximation based on limited sampling; monazite concentrations may prove to vary considerably across the carbonatite ore body as mining progresses. For discussion purposes, applying an ore body estimated to comprise at least 16.7 million tonnes of carbonatite, with an average thorium content of about 0.025 per cent, there would be an estimated resource of at least 4,200 tonnes of thorium at Mountain Pass. Since the estimates as based on limited sampling and extrapolation, it should be considered as an estimate in the lowest level of geological confidence.

16. The mining and processing operation at Mountain Pass is currently devoted only to the recovery and separation of REEs. No plans have been reported by the company to recover the thorium in the foreseeable future. At this time (2015), when the carbonatite of Mountain Pass is mined, processed, and the REEs are separated, the thorium moves with other residues into the tailings impoundment. Thus, it would require modification of the process flow-sheet and/or further reprocessing of the tailings in order to recover the thorium in the future.

IV. Classification of the case study by UNFC-2009

17. As a mine and production operation for REEs, the Mountain Pass mine of Molycorp would be classified using UNFC-2009 as E1.1 F1.1 G1.2. That is, on its basis as a rare earth element operation, it is classified by these categories and sub-categories (Table 1):

- **E1.1** "Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions."
- **F1.1** "Extraction is currently taking place."
- **G1, G2** "Quantities associated with a known deposit that can be estimated with a high level of confidence" (Proven Reserves) and "with moderate level of confidence" (Probable Reserves).

18. In contrast, viewed additionally as a known, unutilized thorium deposit sampled for thorium content at a reconnaissance level, this mineral deposit may be classified as E3.3 F2.3 G3:

- **E3.3** "On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic prospects for economic extraction and sale in the foreseeable future."
- **F2.3** "There are no current plans to develop or to acquire additional data at the time due to limited potential."
- **G3** "Quantities [of thorium] associated with a known deposit that can be estimated with a low level of confidence."

Figure 1.
The Mountain Pass mine of Molycorp, Inc. in Southeast California. This is the only active REE mine in the United States (in 2015). The ore body is a carbonatite intrusion, thought to represent the largest REE resource in the United States
(Photograph by B. Van Gosen, USGS)

Table 1.
REE and thorium resources of the Mountain Pass deposit, California, classified in UNFC-2009 scheme

Mountain Pass deposit	Quantities (tonnes)	Average Grade (%)	CRIRSCO Classification	UNFC-2009 Categories E F G	UNFC-2009 Class	UNFC-2009 Sub-Class
Total REE oxides	1 333 000[a]	7.98 (as oxide)	Proven + Probable Reserves	1.1 1.1 1.2	Commercial Project	On Production
Thorium	4 200	0.025 (elemental weight %)	Inventory[b]	3.3 2.3 3	Non-Commercial Project	Development Not Viable

[a] Proven and probable REE reserves based on an estimated 16,700,000 tonnes of carbonatite ore (grades and tonnages for the REE reserves categories are combined in the public reporting).

[b] Not defined in the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template.

IV. Conclusion

19. The application of UNFC-2009 as a complement to the NEA/IAEA Classification contributes to both a better understanding of the availability of thorium in the United States as well as providing information on how these sources may contribute to future planning and enactment of nuclear energy programmes.

V. References

1. Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA) and the International Atomic Energy Agency (IAEA) (2012) Uranium 2011: Resources, Production and Demand. OECD Report ISBN 978-92-64-17803-8, 487 p. [This is the most recent volume of the series informally referred to as the "Red Book"].

2. Tse, Pui-Kwan (2011) China's rare-earth industry: U.S. Geological Survey Open-File Report 2011–1042, 11 p., *http://pubs.usgs.gov/of/2011/1042/*

3. China National Bureau of Statistics (2010) China statistical yearbook, 2009: Beijing, China, China Statistics Press, 1,032 p. (In Chinese).

4. Gambogi, Joseph (2014) Rare earths, U.S. Geological Survey Mineral Commodity Summaries, *http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/*

5. Gambogi (2011) 2011 Minerals Yearbook—Rare Earths [Advance Release, U.S. Geological Survey], *http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/myb1-2011-raree.pdf*

6. Van Gosen, B.S.; Verplanck, P.L.; Long, K.R.; Gambogi, Joseph; Seal II, R.R. (2014), The rare-earth elements—Vital to modern technologies and lifestyles: U.S. Geological Survey Fact Sheet 2014–3078, 4 p. Available at *http://pubs.usgs.gov/fs/2014/3078/*

7. Wouters, Mark; Selto, Frank H.; Hilton, Ronald W.; Maher, Michael W. (2012) Cost Management: Strategies for Business Decisions, International Edition, McGraw-Hill, p. 535.

8. Long, K.R.; Van Gosen, B.S.; Foley, N.K.; Cordier, Daniel (2010) The principal rare earth elements deposits of the United States—A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010–5220, 96 p. *http://pubs.usgs.gov/sir/2010/5220/*

9. European Commission (2008) Waste Framework Directive, *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098*

10. United Nations Environmental Program (2013) "Guidelines for National Waste Management Strategies Moving from Challenges to Opportunities". ISBN 978-92-807-3333-4.

11. Indian Bureau of Mines (2012) Indian Mineral Yearbook 2011 (Part-II), Rare Earths (Advance Release) (*http://ibm.gov.in/IMYB%202011_Rare%20Earths.pdf*)

12. Gambogi, Joseph (2014) Thorium, U.S. Geological Survey Mineral Commodity Summaries, *http://minerals.usgs.gov/minerals/pubs/commodity/thorium/*

13. Great Western Minerals Group (2014) Great Western Minerals Group company website, *http://www.gwmg.ca/mining-operations/overview*

14. Van Gosen, B.S.; Gillerman, V.S.; Armbrustmacher, T.J. (2009) Thorium deposits of the United States—Energy resources for the future?: U.S. Geological Survey Circular 1336, 21 p. Available at *http://pubs.usgs.gov/circ/1336/*

15. Castor, S.B. (2008) The Mountain Pass rare-earth carbonatite and associated ultrapotassic rocks, California: The Canadian Mineralogist, v. 46, no. 4, p. 779-806.

16. Molycorp, Inc. (2012) Molycorp's rare earth reserves at Mountain Pass increase by 36%, Molycorp, Inc. press release, 9 April, 2012.

17. Staatz, M.H.; Hall, R.B.; Macke, D.L.; Armbrustmacher, T.J.; Brownfield, I.K. (1980) Thorium resources of selected regions in the United States: U.S. Geological Survey Circular 824, 32 p.

United Nations ECE/ENERGY/GE.3/2015/7

Economic and Social Council

Distr.: General
23 February 2015

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Classification

Sixth session
Geneva, 28 April – 1 May 2015
Item 15 of the provisional agenda
Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case Studies – Application of UNFC-2009 to uranium resources in China and Niger

Prepared by the Task Force on Application of UNFC-2009 to Nuclear Fuel Resources

I. Introduction

1. This document focuses on the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to uranium resources in selected deposits in China and Niger.

2. The first case study relates to the application of UNFC-2009 to the uranium resources in the Yili Basin, North West China. In the case study, issues related to In-situ Leaching (ISL) and the use of UNFC-2009 for such projects are raised. ISL, also known as solution mining, is a mining process used to recover uranium through boreholes drilled into a deposit. It involves leaving the ore where it is in the ground, and recovering the minerals from it by dissolving them and pumping the pregnant solution to the surface where the minerals can be recovered. There are similar cases in Australia, Kazakhstan and the United States of America which generate significant debate when handled only with the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template, due to the fact that the recovery factor is usually a major uncertainty.

GE.15-03462 (E)

1503462

Please recycle

3. The second case study focuses on the application of UNFC-2009 to the Azelik Uranium Deposit located in the north-western region of Niger.

4. In both case studies the uranium resources were originally classified according to the China Mineral Reserves and Resources Classification System (CMRRCS).

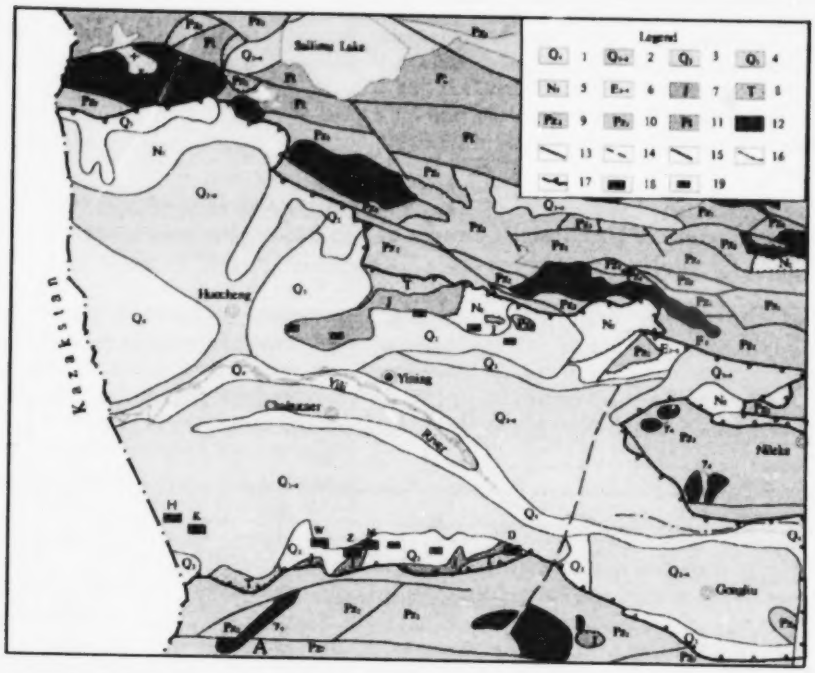
II. Application of UNFC-2009 to the Uranium Resources in the Yili Basin, China - A case study on the mapping of CMRRCS to UNFC-2009

5. This case study was prepared with the technical input of Mr. Li Shengxiang and Mr. Yu Hengxu of the China National Nuclear Corporation (CNNC), Mr. Harikrishnan Tulsidas of the International Atomic Energy Agency (IAEA) and Mr. Brad Van Gosen of the United States Geological Survey (USGS). The case study provides considerations related to the application of UNFC-2009 to estimates of uranium resources in the Yili Basin, North West China. The uranium resources of this basin were originally classified according to the China Mineral Reserves and Resources Classification System (CMRRCS) and this case study demonstrates that the quantities can be transparently transferred to UNFC-2009.

A. Uranium Exploration and Mining in the Yili Basin

6. The Yili Basin, situated in the western part of the Tianshan Tectonic Belt, North West China, is a Meso-Cenozoic intermountain basin developed on the basement of an old Precambrian block (Figure 1). The coordinates of the centre of the Yili Basin are E81°05, N43°50.

Figure 1.
Geological map of the Yili Basin



Legend: 1-Holocene; 2-Upper Pleistocene-Holocene; 3-Middle Pleistocene; 4-Lower Pleistocene; 5-Pliocene; 6-Eocene-Oligocene; 7-Jurassic; 8-Triassic; 9-Upper Paleozoic; 10-Lower Paleozoic; 11-Proterozoic; 12-Hercynian granite; 13-fault; 14-inferred fault; 15-buried fault; 16-unconformity; 17-boundary of the basin; 18-U Deposit; 19-U occurrence; K-Kujiertai deposit; W-Wukuerqi Deposit; Z-Zhajistan Deposit; M-Mengqiguer Deposit; D-Daladi Deposit; H-Honghaigou Deposit.

7. The uranium mineralization is mainly hosted in the coal-bearing clastic rocks of the Shuixigou Group ($J_{1-2}sh$), the Lower-Middle Jurassic (Figure 1). The ore-hosting Shuixigou Group ($J_{1-2}sh$) can be further divided into three formations, namely, Badaowan Formation (J_1b), Sangonghe Formation (J_1s) and Xishanyao Formation (J_2x)[1,2].

8. Uranium prospecting work began in this region in the early 1950s. During the 1950s and 1960s, the prospecting focused on coal-type uranium resources; two coal-type deposits – the Daladi Deposit and the Mengqiguer Deposit – were discovered during that time. After being suspended for about 20 years, the prospecting work restarted in the early 1990s and focused on in-situ leach (ISL) amenable sandstone-type uranium deposits in the southern margin of Yili Basin. Following 25 years of geological exploration efforts, five in-situ

[1] Li Shengxiang et al., Geologic Evolution and Uranium Metallogenic Regularity of the Yili Basin, Sandstone-type Uranium Deposits in China: Geology and Exploration Techniques, Atomic Energy Press, 2002, 9: p. 53-64.

[2] Lin Shuangxin, Wang Baoqun, Li Shengxiang. 2004. Characteristics of uranium mineralization and ore-controls of Kujieertai Deposit, Yili Basin, Xinjiang Autonomous Region. IAEA-TECDOC-1396. p. 79-90.

leachable sandstone-type uranium deposits – the Mengqiguer, Zhajistan, Wukuerqi, Kujiertai and Honghaigou Deposits – have been delineated, with the total uranium resources amenable to ISL extraction estimated at over 30,000 tU (metric tons of uranium).

9. Uranium production and trial production activities using the ISL method are currently ongoing in the Mengqiguer, Zhajistan, Wukuerqi and Kujiertai Deposits, forming the largest uranium production centre in China. The total production capacity of the four deposits is around 400 tU per annum, and will expand to 500 tU per annum in the near future. Exploration work continues in the existing deposit extensions and their adjoining areas.

B. Classification of Uranium Resources of Yili Basin with the current China Categorization System

10. The current China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals was established in 1999[3,4]. It was formulated on the basis of the principles of the United Nations Framework Classification for Reserves/Resources – Solid Fuels and Mineral Commodities of 1997 (UNFC-1997). Both these systems use E, F, G axes (see Table 1). As shown in Table 1, CMRRCS has 16 categories.

Table 1.

China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals

<table>
<tr><td rowspan="3">Economic Viability</td><td colspan="4">Geological Study</td></tr>
<tr><td colspan="3">Identified mineral resources</td><td>Potential mineral resources</td></tr>
<tr><td>Measured</td><td>Indicated</td><td>Inferred</td><td>Prognostic</td></tr>
<tr><td rowspan="4">Economic</td><td>Mineable Reserve (111)</td><td colspan="2" rowspan="2"></td><td rowspan="6"></td></tr>
<tr><td>Basic Reserve (111b)</td></tr>
<tr><td>Pre-mineable Reserve (121)</td><td>Pre-minable Reserve (122)</td><td rowspan="5"></td></tr>
<tr><td>Basic Reserve (121b)</td><td>Basic Reserve (122b)</td></tr>
<tr><td rowspan="2">Marginal Economic</td><td>Basic Reserve (2M11)</td><td></td></tr>
<tr><td>Basic Reserve (2M21)</td><td>Basic Reserve (2M22)</td></tr>
<tr><td rowspan="2">Sub-Marginal Economic</td><td>Resource (2S11)</td><td></td></tr>
<tr><td>Resource (2S21)</td><td>Resource (2S22)</td></tr>
<tr><td>Intrinsically Economic</td><td>Resource (331)</td><td>Resource (332)</td><td>Resource (333)</td><td>Resource (334)</td></tr>
</table>

Note: (i) the first number represents economic viability, where 1 = economic, 2M = Marginal Economic, 2S = Sub-Marginal Economic, 3 = Intrinsically Economic. (ii) The second number represents status of project feasibility study, where1 = feasibility study, 2 = pre-feasibility study, 3 = Scoping study. (iii) The third number represents geological study, where 1= measured, 2 = indicated, 3 = inferred, 4 = prognostic. (iv) b = mineable reserve with no consideration of mining losses.

[3] Classification for resources/reserves of solid fuels and mineral commodities, China National Standard GB/T17766-1999, issued by the State Bureau of Quality and Technical Supervision (in Chinese).

[4] Specifications for uranium mineral exploration, China Geological and Mineral Resources Industry Standards DZ/T 0199-2002, issued by the Ministry of Land and Resources P.R. China (in Chinese).

11. The mapping of CMRRCS to UNFC-2009 is shown in Table 2.

Table 2.

Mapping of CMRRCS to UNFC-2009 Categories

No		CMRRCS			UNFC-2009		
		E	F	G	E	F	G
1	Economic Measured Minable Reserve	1	1	1	1	1	1
2	Economic Measured Basic Reserve	1	1	1b	1	1	1
3	Economic Measured Pre-minable Reserve	1	2	1	1	1 2, 1 3	1
4	Economic Measured Basic Reserve	1	2	1b	1	1 2, 1 3	1
5	Economic Indicated Pre-minable Reserve	1	2	2	1	1 2, 1 3	2
6	Economic Indicated Basic Reserve	1	2	2b	1	1 2, 1 3	2
7	Marginal Economic Measured Basic Reserve	2M	1	1	2	2 1	1
8	Marginal Economic Measured Basic Reserve	2M	2	1	2	2 1	1
9	Marginal Economic Indicated Basic Reserve	2M	2	2	2	2 1	2
10	Sub-Marginal Economic Measured Basic Reserve	2S	1	1	2	2 2	1
11	Sub-Marginal Economic Measured Basic Reserve	2S	2	1	2	2 2	1
12	Sub-Marginal Economic Indicated Basic Reserve	2S	2	2	2	2 2	2
13	Intrinsically Economic Measured Resource	3	3	1	2, 3 2, 3 3	2 1, 2 2, 2 3	1
14	Intrinsically Economic Indicated Resource	3	3	2	2, 3 2, 3 3	2 1, 2 2, 2 3	2
15	Intrinsically Economic Inferred Resource	3	3	3	2, 3 2, 3 3	2 1, 2 2, 2 3	3
16	Intrinsically Economic Prognostic Resource	3	3	4	3 2	3	4

12. Classification of the uranium resources of the Yili Basin was undertaken according to the mapping of CMRRCS to UNFC-2009 that is shown in Table 2 and results are shown in Table 3.

Table 3.

Classification of the Uranium Resources of the Yili Basin

Deposits	UNFC-2009 Class	UNFC-2009 Sub-Class	UNFC-2009 Categories	CMRRCS
Mengqiguer-2 (sandstone type)	Commercial Projects	On production	E1 1F1 1G2, E1 1F1 1G3	122b,332[a] 333
Mengqiguer-1 (coal type)	Non Commercial Projects	Development not viable	E3 3F2 3G2, E3 3F2 3G3	332 333
Kujiertai	Commercial Projects	On production	E1.1F1.1G1, E1 1F1 1G2, E1 1F1 1G3	121b, 122b,332[a] 333
Zhajistan	Commercial Projects	On production	E1 1F1 1G1 E1.1F1.1G2, E1.1F1.1G3	121b, 122b,33[a] 333
Wukuerqi	Commercial Projects	On production	E1 1F1 1G2, E1 1F1.1G3	122b,33[a] 333
Daladi	Non Commercial Projects	Development not viable	E3.3F2 3G2, E3.3F2 3G3	332 333
Honghaigou	Potentially Commercial Projects	Development Pending	E2F2.1G3	333

[a] Because definitive feasibility studies (DFS) or pre-feasibility studies (PFS) for the development of the deposit were done in the central area of the deposit and did not cover the extension area, the resources of the extension part of the deposit have not been converted into 122b from 332 in the existing CMRRCS report.

C. Application of UNFC 2009 to the uranium deposits of the Yili Basin

1. Mengqiguer Deposit

13. The Mengqiguer Deposit is the largest uranium deposit in the Yili Basin. The deposit accounts for about 45 per cent of the total uranium resources of the Basin. The uranium ore bodies are mostly hosted in the Xishanyao Formation and the Sangonghe Formation.

14. The uranium mineralization discovered during the 1950s and 1960s was found to be hosted in coal beds (named as Mengqiguer-1). The quantity is small. Since this material is difficult to process, this kind of coal type uranium mineralization is considered as "Development not viable" with categories E3.3 F2.3 G2, E3.3 F2.3 G3.

15. The uranium mineralization discovered after 2000 was found in permeable sandstone layers, which allows the uranium to be extracted with the ISL method (named as Mengqiguer-2). The ISL-amenable uranium resources of the deposit account for about 43 per cent of the total resources of the basin. Since the on-going trial uranium production with the ISL method in the deposit shows positive commercial results, this type of sandstone type uranium mineralization is considered as "On production" with categories E1.1 F1.1 G2, E1.1 F1.1 G3 (table 3). More geological work needs to be carried to increase the geological confidence of these resources.

2. Kujiertai Deposit

16. The Kujiertai Deposit is the second largest uranium deposit and the first ISL-mining uranium deposit in the Yili Basin, and also the first commercial ISL uranium production centre in China. The deposit accounts for about 23 per cent of total uranium resources of the basin. It was discovered in early1990s and the uranium ore bodies are mostly hosted in the permeable sandstone layers of the Xishanyao Formation and the Badaowan Formation. The uranium production of the deposit began in middle of 1990s using the ISL method. The uranium mineralization is considered as "On production" with categories E1.1 F1.1 G1, E1.1 F1.1 G2, E1.1 F1.1 G3.

3. Zhajistan Deposit

17. The uranium ore bodies of the Zhajistan Deposit are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources constituting about 10 per cent of the total resources of the basin. The uranium mineralization is hosted in permeable sandstone layers and is being mined with the ISL method, in which case the uranium resources are considered as "On production" with categories E1.1F1.1G1, E1.1F1.1G2, E1.1F1.1G3.

4. Wukuerqi Deposit

18. The uranium ore bodies of the Wukuerqi Deposit are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources constituting about 7 per cent of the total uranium resources of the basin. The uranium mineralization is hosted in permeable sandstone layers and is being mined with the ISL method, so the uranium resources are considered as "On production" with categories E1.1 F1.1 G2, E1.1 F1.1 G3. However, more geological work needs to be carried out to increase its geologic assurance.

5. Daladi Deposit

19. The Daladi Deposit is the earliest discovered uranium deposit in the Yili Basin. The uranium ore bodies are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources being less than 3 per cent of the total resources of the

Basin. The uranium mineralization is hosted in the coal beds and is difficult to process, so these uranium resources are considered as "Development not viable" with categories E3.3F2.3G2, E3.3F2.3G3.

6. Honghaigou Deposit

20. The Honghaigou Deposit is a new Deposit that was discovered in recent years, and the exploration and the pre-feasibility studies are still ongoing in the Deposit. The uranium ore bodies are mostly hosted in the Upper Jurassic and the Xishanyao Formation with the uranium resources constituting about 12 per cent of the total resources of the basin. The uranium mineralization is classified into "333" in the current CMRRCS. However, considering that the uranium mineralization is hosted in permeable sandstone with similar mineralization characteristics to that of the Kujiertai Deposit, and that the deposit can be mined using the ISL method, the uranium resources are considered as "Development Pending" with categories E2 F2.1 G3.

D. Conclusions

21. From this case study on the application of UNFC-2009 to the uranium resources in the Yili Basin, it can be concluded that if a comprehensive consideration of the project socio-economic viability and project status and feasibility is undertaken, the mapping of CMRRCS Classes to UNFC-2009 Classes will be relatively easy and straight forward. UNFC-2009, in particular with its Sub-classes, is a very useful uranium resources categorization tool because it can provide an overall picture of a uranium project. Additionally, UNFC-2009 can express the project more comprehensively and more precisely than UNFC-1997 and CMRRCS, especially in relation to project status and feasibility.

III. Case Study – Application of UNFC-2009 to the uranium resources of the Azelik Deposit, Niger

22. This case study was prepared with the input of Mr. Li Shengxiang of the China National Nuclear Corporation (CNNC), Mr. Harikrishnan Tulsidas of IAEA and Mr. Brad Van Gosen of USGS.

23. The Azelik Uranium Deposit is located in the north-western region of Niger. It is a sandstone-type uranium deposit hosted in the Cretaceous strata of the Tim Mersoï Basin. Based on the geological survey, core observation and documentation, the uranium mineralization is related to hydrothermal fluid flow[5].

24. In 2006, the China National Nuclear Corporation acquired the project and conducted an estimation of the uranium resources through application of the China Mineral Reserves and Resources Classification System (CMRRCS). The resource estimation was carried out prior to the Definitive Feasibility Study (DFS) being undertaken. In 2008, China National Nuclear Corporation completed the DFS for the project, following which construction of the mine began.

[5] Nie Fengjun et al. 2009. Progress report on nuclear science and technology in China (Vol.1). Proceedings of Academic Annual Meeting of China Nuclear Society, No.6.

25. The aggregate uranium resources estimation according to CMRRCS before carrying out the DSF was 13,692.3 metric tons of uranium (tU). After completing the DFS, the aggregate resources according to CMRRCS were estimated to be 12,763.1 tU (Table 4).

Table 4.

Estimated uranium resources of the Azelik Deposit, calculated before and after the Definitive Feasibility Study (DFS)

Deposit	*Type*	*Resources before DFS*			*Resources after DFS*			
		CMRRCS Category	CRIRSCO[a] Template	tU	CMRRCS Category	CRIRSCO Template	NEA/IAEA "Red Book" Classification	tU
Azelik	Sandstone	331	Measured Resources	18,20 80	111	Proven Reserves	RAR (<USD 130/KgU)	1,820 8
		332	Indicated Resources	8,788 3	122[b]	Probable Reserves	RAR (<USD 130/KgU)	8,664 4
		333	Inferred Resources	3,083 2	2M22[b]	Inferred Resources	IR (<USD 130/KgU)	2,277 9
Total				13,692 3				12,763.1

[a] Committee for Mineral Reserves International Reporting Standards (CRIRSCO).

[b] In view that the geological confidence was not high enough due to insufficient infill drilling during the DFS, China National Nuclear Corporation transferred the former 332 into 122 and 333 into 2M22 by excluding some high-cost resources. The feasibility study level was lowered to pre-feasibility study results rather than moving the resources into proven reserves.

A. The Case Study

26. The Estimated uranium resources of the Azelik Deposit after the DFS were classified according to the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). The mapping to the Organisation of Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)/International Atomic Energy Agency (IAEA) resource reporting scheme (also known as the "Red Book") and CMRRCS is shown in Table 5. This is aided by the mapping scheme described for CMRRCS and UNFC-2009.

Table 2.

Estimated uranium quantities in the Azelik Project classified under UNFC-2009 (as at December 2010)

Project	UNFC-2009				NEA/IAEA "Red Book" Classification			CMRRCS	
	Class	Sub-class	Categories	(tU)	Production Centre Status	Classification	(tU)	Class	(tU)
Azelik	Commercial Project	On Production	E1 1F1.1G1	1,820.8	Existing	RAR[a] <$130/Kg	10,485.2	111	1,820.8
			E1 1F1.1G2	8,664 4				122	8,664.4
Azelik	Potentially Commercial Project	Development Pending	E2F2.1G3	2,277 9	Prospective	IR[b] <$130/Kg	2,277.9	2M22	2,277.9
Total				**12,763.1**			**12,763.1**		**12,763.1**

[a] Reasonably Assured Resources.

[b] Inferred Resources.

B. Conclusions

27. In this Case Study, the cost categories as used in the NEA/IAEA "Red Book" classification are also used for each of the Classes. This example shows that mapping of the existing CMRRCS categories and quantities to the NEA/IAEA "Red Book" Classification and UNFC-2009 can be carried out in a straightforward manner.

28. Even though the mapping of UNFC-2009 to CMRRCS has been defined only at a Class level, the use of Sub-classes – as in this case study – can add further information about the project and application of the UNFC-2009 principles and generic specifications. Thus, the full granularity of UNFC-2009 can be applied to derive maximum benefits.

IV. Observations, Conclusions and Recommendations

29. The work undertaken in preparing the two case studies usefully demonstrates that quantities can be transparently transferred to UNFC-2009 from CMRRCS.

30. The Yili Basin case study highlighted issues related to the use of UNFC-2009 for In-situ Leaching (ISL). It was noted that there are examples in Australia, Kazakhstan and USA where the CRIRSCO Template is applied to ISL projects. In some cases this can generate debate due to the fact that the recovery factor is usually a major uncertainty. Application of UNFC-2009 can facilitate representation of this uncertainty through use of the G-axis categories.

31. The Azelik Uranium Deposit case study demonstrates that mapping of the existing CMRRCS categories and quantities to the NEA/IAEA "Red Book" Classification and UNFC-2009 can be carried out in a straightforward manner.

32. Even though the mapping of UNFC-2009 to CMRRCS has been defined only at a Class level, the use of Sub-classes – as in the Azelik Uranium Deposit case study – can add further information about the project and application of the UNFC-2009 principles and generic specifications. Hence, the full granularity of UNFC-2009 can be applied to derive maximum benefits.

33. The two case studies serve to confirm that there would appear to be a straightforward relationship between the CMRRCS Classes and the UNFC-2009 Classes and hence consideration may now be given to the possible development of a Bridging Document between the two systems.